VIII. *On the Development of the Skull in* Lepidosteus osseus.

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[PLATES 30–38.]

IN the early part of 1879 I received from Professor A. AGASSIZ a large series of eggs and embryos of *Lepidosteus*, which by the help of Mr. GARMAN he had obtained from the Black Lake the year before. These specimens, carefully preserved in fifty-four small bottles, Professor AGASSIZ put into my hands to be worked out by Mr. BALFOUR and myself. A few years before I had received from Professor BURT G. WILDER some larger young of this Fish, which extended the "stages" for us considerably; and several adults obtained by Mr. BALFOUR, and one which I received from Professor FLOWER, made up the total of our materials. The present communication is the result of my own researches into the growth of the skull and visceral arches. Mr. BALFOUR, assisted by my son, Mr. W. N. PARKER, has prepared an elaborate memoir on the embryology of this important type, to which are added observations on the structure of various organs in the adult.

When our work was scarcely begun I prevailed upon Dr. TRAQUAIR to work out the *adult skull*, and that piece of research is, I believe, nearly finished, so that this *Holostean Ganoid* will soon have had a fair amount of attention given to it.

My observations extend over a series of embryos and young from one-third of an inch to four and a-half inches in length. The larger young are already quite like the adult; but as Dr. TRAQUAIR'S paper has not yet been sent in to the Royal Society, I shall preface mine by a short description of the adult skull: it will give the same interpretation as the promised memoir by my talented friend, for we have had several discussions upon the nomenclature and meaning of the various parts, and are of one mind as to their names and nature.

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The skull of the adult Lepidosteus.

This skull, which belongs to the long-beaked variety, is more than a foot long, and the foremost two-thirds of its length belongs to the "rostrum," which is gradually attenuated from behind forwards, and then dilates gently at the fore end. The olfactory sacs are very small, and instead of being placed close in front of the antorbital region, are carried to the end of the snout, and have on each side a pair of holes bounded by small bony plates. The orbits are a little above half an inch across, and they are bounded by a perfect "circumorbital" series. The auditory capsules are impacted into the walls of the hind skull, which at the sides is only about one-twentieth the length of the head. The occipital condyle is behind the skull; the condyles of the quadrate are in front of the orbits. There is no fontanelle in the perfect skull—that space is entirely covered by large ganoid scutes.

A. *On the superficial plates or "scutes."*

Beginning at the occipital roof, we find the hind skull covered with two large plates that represent the parietals; here, at once, we see how variable these scutes are, which answer to *much more* than the investing bones in the higher types, for there is, on the left side (in my specimen), an irregularly four-sided "dermo-occipital," the inner edge of which passes over the mid-line a little. Thus the right parietal is much larger than the left. Outside each parietal there is a somewhat smaller scute—the squamosal; this bone finishes the roof. The two or three small, irregular scutes behind the squamosal are "post-temporals," and serve as fixing-points to the *clavicular series* of the shoulder-girdle; they are post-cranial.

Outside the hinder part of the squamosal there are two smallish additional "temporal" scutes, wedged in above the "opercular."

In front of the parietals and squamosals we see the frontals; they interdigitate by large, sharp, sutural teeth, with those bones, and then run on over the orbital region, and over the hinder two-fifths of the rostrum. They are elegantly narrow-waisted (taken together) in the orbital region, and they contract into sharp styles in front, where they embrace the next pair.

These next bones are the "ethmo-nasals," or superficial splints of the ethmoidal region; they are close together along the mid line, sharp and narrow between the fore part of the frontals, and then wider; they reach, behind, within an inch and a-half of the orbits, and then run forward up to the nasals (proper). These latter are small, short, widely-crescentic plates, that lie on the small, distal, olfactory sacs; they are the *ossa terminalia* of the upper *mucous* series. The nasals finish the skull-beak above; below, an oblique transverse plate of bone supports the prenasal pad or remnant of the larval sucking-disk; it may be called the "prenasal bone." The nasal bone sends a process obliquely across the nasal opening; this bone lies in the membranous bar, which was developed early, dividing the "nostril" into two holes. Behind and under the prenasal and nasal bones we have the two short thick premaxillaries, which carry some very large, sharp teeth, as well as a rasp of smaller denticles. These bones have a palatal as well as a dentary region; and between the two the bone is punched with holes by the foremost teeth of the mandible, as in the Crocodile; the palatine processes diverge a little, behind, to embrace the vomers.

The vomers are very long, thin styles of bone, closely co-adapted along the mid line of the palatal region of the rostrum up to its hinder fourth; they have their lower face covered with a rasp of very small teeth.

Outside these there is on each side a larger splint, which reaches from the premaxillary to the antorbital space. The outside of each bone is bevelled and helps to carry the large sub-marginal teeth; these are the *superficial* palatines. Outside these, on the margin, we have the "maxillary chain" of mucous bones, about fifteen on each side, but some of them are ankylosed together; they increase in length from before backwards. The preorbital (prequadrate) space is overlapped by the last two of this chain; these are free; the larger front bone answers to the free part of the "os mystaceum" of an Acanthopterous Teleostean; the lesser scale to its jugal. A large splint passes along by its sharp fore end, on the inside of the parosteal palatine, nearly to its middle; it broadens rapidly at the prequadrate space and turns downwards, as a rounded wing. It is notched below close in front of the quadrate condyle, and then passes backwards as a large lanceolate splint, which is closely applied to nearly all the inner face of the mandibular suspensorium; this is the pterygoid bone, the osseous counterpart of the whole palato-quadrate arcade. Above the broad hind part of that arcade, close in front of the basi-pterygoid articulation, there is a much smaller lanceolate splint, the meso-pterygoid; it lies inside, but rises somewhat above the obliquely directed suspensorium. An oblong splint, rather larger than the last, lies on the outside of the lower face of the suspensorium, and is dilated where it fits to the enlargement at the quadrate condyle; this is the "preopercular": a very different bone from its counterpart in the Teleostei, and like the lower part of a Frog's squamosal. These four—the superficial palatine, the pterygoid, the mesopterygoid, and the preopercular—are the splints of the palato-quadrate arcade; the rest of the mandibular splints are on the free ramus, and will be described soon. There is a perfect "circum-

orbital" series of small, thick ganoid scutes, which run before and behind into other tracts, and are not separated as a mere ring. The upper region is composed of a chain of larger bones than the rest, and this tract is continued forwards as three bones, narrowing forwards, in the *preorbital* region, over the "prequadrate space." Behind and above, these larger bones run backwards under the squamosal until they become the "post-temporals" to which the clavicular bones are attached. They are the direct cephalic continuation of what in the Teleostei are known as the "lateral line" series. A row of small scutes runs straight down in front of the orbit from the preorbital band; the lowest of these binds on the quadrate, over the hinge, and over the foot of the preopercular. From this angular bone there is an increasing number of scutes under the orbit, and those behind the orbit become a solid tesselated pavement (part of which I have just described as lying directly beneath the squamosal), and this pavement lies on the edge of the lower part of the interopercular and covers all its ascending part.

This most remarkable "interopercular" is much like the preopercular of the Teleosteans, and might easily be mistaken for it. It is a huge plate bent upon itself at a right angle; the ascending part is half the size of the lower region, and whilst covered by the facial "pavement," itself covers the hyomandibular and symplectic; that part is pointed above. The lower region of the bone is a large externally ganoid tract, pointed in front, ear-shaped behind, hollow within, and coiled inwards. Behind the facial pavement, and articulated by a cup-like facet to the "opercular process" of the hyomandibular, is the opercular bone; it is four-sided, but narrow above where it articulates with the post-temporal. Its broad lower edge is toothed and overlaps the subopercular; its hind face is free and forms the upper half of the free edge of the *operculum*. The "subopercular" forms the lower half of that edge; it is a broad plate with a rounded lower and hinder margin, and is uncinate in front and above, where it is wedged in between the interopercular and opercular. These three bones—the interopercular, the opercular, and the subopercular—belong to the hyomandibular region. The splints of the mandible are ganoid where they are exposed. The main bone is the "dentary"; it covers nearly all the outside of the ramus and the upper and lower edges within. On the inside, between those edges, MECKEL'S cartilage is hidden in its foremost two-thirds by a long, thin, narrow splint, the "splenial." The rami of the mandible are close together, half-way, backwards, and then gently diverge. The coronoid region is very high, large, and incurved. The "coronoid" bone flanks the front of this part as an oblique splint, and the "supra-angulare" covers the smooth, convex outside; a short, thick, wedge of bone, the "angulare," is set on to the angle of the ramus. These five bones—the dentary, splenial, coronoid, supra-angulare, and angulare—are the normal investing bones of the mandible. In the lower part of the hyoid arch there are three narrow flattened rays, from an inch to an inch and a-half in length, attached to the outer face of the "epi-hyal"; these are the "branchiostegals," and they correspond in number to what we find in the Cyprinoid Teleosteans.

Under the skull there is a long beam of bone, reaching to the middle of the vomers, lying there somewhat above them, and then escaping, showing a free keel; this is the "parasphenoid." It runs backwards, gently broadening, and then narrowing again, and gradually losing its keel, up to the "basipterygoid processes," it flanks them with a small pair of wings, and is then alate again, more extensively, under the "sacculus" of the ear, and ends as two flat processes under the basioccipital, and nearly reaching to its end.

B. *On the endo-cranial bones.*

In the hind skull I fail to find a distinct supraoccipital under the roof, for the exoccipitals meet there, and are separated only by a narrow tract of cartilage. The basioccipital is large, and projects beyond the arch; its hollow articular face is transverse, and notched above and below. The exoccipitals are large, and finish the arch above. The auditory capsule is invested by *four* cartilage bones on each side, viz.: a large prootic, a middle sized epiotic, and a small opisthotic, and the sphenotic bone which is of the average size, and ossifies the post-orbital angle of the endocranium, where the fore part of the auditory capsules are imbedded. I can find no "pterotic" under the squamosal. There are two alisphenoids, and they ossify the basipterygoid processes, but I find no distinct basisphenoid, presphenoid, nor orbito-sphenoids; although after the brain cavity has retreated, losing much of its front part, a bony plate is found in the presphenoidal region. This plate is thin, fenestrate, and rests upon the parasphenoid. I believe that it is formed by the coalescence of the once distinct lateral ethmoids, which were at first formed in the sides of the fore part of the chondrocranium, like the primary elements of the Frog's "girdle-bone" (see Plate 38, figs. 2, 3, *l.eth.*). The rostral part of the endocranium is, I believe, unossified, even in the adult.

The quadrate and metapterygoid bones occupy only part of the mandibular suspensorium; the rest remains unossified; the metapterygoid bone takes up the part which answers to the pedicle and rudimentary otic process; a facet of cartilage covers it where it articulates with the "basipterygoid process." The hyomandibular is fenestrate and well ossified; it is only half as large as the mandibular suspensorium. A short tract of cartilage separates its upper from the slender long symplectic.

The articulare is a strong solid mass of bone, capped by a saddle-shaped condyle for articulation with the quadrate.

The small inter-hyal piece is not ossified, but the epi-, cerato-, and hypo-hyals are; the long *double* basi-hyal ("ento-glossal") does not become solid bone, but it is *endosteally* hardened. The fore part of the basi-branchial series is slightly ossified, the arches are as well ossified as in the ordinary Teleostei; thus there are in the first four arches a pharyngo, epi-, cerato-, and hypo-branchial piece, largely converted into bone; the fifth is ossified, but it only has the cerato-branchial element in it.

First Stage.—Recently hatched young of Lepidosteus, $2\frac{3}{4}$ *to* $4\frac{1}{2}$ *lines long.*

At this stage (Plate 30, figs. 1, 2) the mesocephalic flexure is at its fullest development, but the angle formed by the meeting of the *para*-chordal and *pro*-chordal regions is very open. Moreover, the bend appears less than it is, for the snout is very large and dilated, and its axis is coincident with that of the cerebral hemispheres (C^{1a}.) and of the mid brain (C^{2}.).

The fissure, however, between the fore and hind brain (C^{3}.), and below the mid brain, is very large, and is turned backwards considerably, above; the notochord (*nc.*) seeks to ascend into this space, but only rises one-third of the way to the top; the third nerve descends in this cavity to reach the orbital muscles.

In the sectional figures given to illustrate this stage, very little of the primordial cranium comes into view; it is not yet formed into consistent cartilage, but the "embryonic cartilage" is sufficiently developed to show the cranial and facial rudiments.

The pituitary body (*py.*) is distinguishable from the palatal skin, and it is quite free above, the infundibulum (*inf.*) lying over it.

In both figures (Plate 30, figs. 1 and 2, cl^{1-4}.) the clefts and visceral folds are visible on their inner or *hypoblastic* aspect; in the more advanced specimen a rod of solidifying tissue was seen as cut through in six of these, namely, the mandible, hyoid, and four of the branchial arches (*mn.*, *hy.*, br^{1-4}.)—all but the *fifth*, which remains rudimentary.

The heart (*h.*) is seen impacted between the mandibular rudiment (*mn.*) and the yolk (*y.*); it thus lies as far forwards as the snout.

The notochord (*nc.*) is very large, and in the more advanced specimen (Plate 30, fig. 2) the terminal hook of this cephalic end of the rod is fixed in between the infundibulum (*inf.*) and the swelling antero-inferior part of the hind brain (C^{3}.).

Second Stage.—Recently hatched young of Lepidosteus, 5 *to* $5\frac{1}{2}$ *lines long.*

In somewhat larger specimens (about 11 millims. long) I was able to make preparations of the whole chondrocranium (Plate 30, fig. 3): a sectional view is given of a somewhat larger specimen (Plate 30, fig. 4).

The section shows that the skull is rapidly straightening, but of course the great *clinoid fissure* is never obliterated. This is formed by the primordial flexure, and is always permanent in the Vertebrata; but the flexure itself is not so great in this type as in the *Amphibia* and the "Amniota."

The notochord (Plate 30, fig. 4, *nc.*) is not traceable so far up in the clinoid region as it was; the pituitary body (*py.*) is still independent of the infundibulum (*inf.*).

In the dissected skull (Plate 30, fig. 3) the basal and facial parts alone are chondrified, the sides and roof are entirely membranous; the cartilage is still very fragile, but quite differentiated from the surrounding connective-fibre cells. The chondrocranium

proper is at present composed of two bands of cartilage, which run from the atlas to the large suctorial snout (*s.d.*); the lateral structures are the auditory capsules and the visceral arches.

The basal pair of bands (Plate 30, fig. 3, *iv.*, *tr.*) are thickest behind and at the fore end; for two-fifths of their length they embrace the notochord by their inner edge; they then diverge from each other so as to form a large spindle-shaped space (*py.*) in front of which, for an eighth of their whole length, they approximate, but do not come into contact with each other.

These dilated fore ends of the basal bands are as broad as the parachordal part behind (*iv.*), but are not so thick; they are conjugated by a tract of embryonic cartilage, the rudiment of the "intertrabecula" (*i.tr.*); they themselves are the rudiments of the cornua trabeculæ (*c.tr.*). The bowed interorbital part of the basal bands are the trabeculæ (*tr.*), they are only half the width of the hind and fore parts; these out-bent bars do not merely fence in the small pituitary body, they embrace the base of the fore-brain.

The free, ascending, blunt end of the cranial notochord (*nc.*) is twisted a little to the left—it may curve either way, but the appearance is partly due to artificial pressure; it is not invested by a large ascending "posterior clinoid" cartilage, as in the *Amniota*, for that tract is very small and very late in appearance in *Lepidosteus*. The *pro*-chordal part of the basal bands is bent somewhat upon the *para*-chordal part. Behind the exit of the 9th and 10th nerves and the hind face of the auditory capsules the investing bars (*iv.*) thin out, and end in a sharp edge in front of the 1st vertebra.

The auditory capsules (*au.*) are of a short oval shape; they are largely chondrified, but the layer of cartilage is very thin; below, there is an oval fenestra, still membranous (*au.f.*); it is about two-fifths the length of the capsule. The capsules and the investing bars are only connected together by embryonic cartilage at present; the convexity of the capsules has produced a corresponding concavity in the side of each bar. The horizontal canal bulges over the lower convex part, which contains the otolith; thus there is a rudimentary "tegmen tympani." Rudiments of all the framework of the visceral arches are now present, but the segmentation of these parts is imperfect. The skeleton of the first and second arches—mandibles and hyoid—is massive; that of the branchial arches is very delicate. The pier of the mandibular arch (*p.pg.*, *q.*, *pd.*) is not a mere "pterygo-quadrate," as in the Selachians, Teleostei, and Urodeles, but is a "palato-quadrate," as in the Anura. This arises from the primary continuity of the ethmo-palatine cartilage with the pterygoid fore-growth of the mandibular suspensorium; and this is not all, for the *palatine region* of the bar is also *primarily continuous* with the trabecula at its dilated fore end.

The "pedicle" of this compound suspensorium is not *fixed*, as in the Tadpole, but *free*, as in the metamorphosed Frog; as soon as it is sufficiently developed to articulate with the basal bar, it will then, at that part, correspond very accurately with what we find in the adult Frog. At present this palato-quadrate, or suspensorial cartilage is

roughly scythe-shaped, the "blade" being behind, and lying between the auditory capsule and the narrowing basal band, whilst the "handle" is in front, and is glued to the trabecula. The blade is shorter than the handle, and on its heel it has an oval, condyloid facet, which looks forwards and a little outwards and downwards; it is pinched a little behind this facet, and then becomes an apiculated lanceolate blade. The handle is oval in section, narrow at first, and then wider as it turns inwards at its junction with the trabecula. A free bar, rather shorter than the "handle," and having its thick end reversed, or behind, articulates by a flat facet with the flat facet of the suspensorium. This is MECKEL'S cartilage, or the free mandible (*mk.*).

Already, in the coronoid region, this short lower jaw is elevated into a crest; its lower edge is convex, its upper concave, and its end is blunt; it reaches nearly as far forwards as the palatine region of the suspensorium. Between the convex hind margin of the first arch (suspensorium and mandible) and the concave fore margin of the next (the hyoid) arch there is a *hypoblastic pouch* (see Plate 30, figs. 1 and 2, cl^1.), but this first cleft does not open on the outside, like the hyo-branchial and four branchials.

The hyoid arch consists already of *four* segments on each side, with the rudiment of a median conjugating bar, composed of embryonic cartilage. The pier (*hm.*) of the hyoid arch, like its counterpart in the Mammal, is anvil-shaped; this is the hyomandibular, with its symplectic process, the counterpart of the pterygoid fore-growth of the mandibular pier or suspensorium.*

At present it is only a fourth less than the pier in front of it; but it becomes relatively much less, instead of much larger, as in the Teleostei. The hyomandibular is now a solid mass of cartilage, concave above, bilobate below, and sending upwards, to the auditory capsule, a thick process, and downwards, to the articular process of the suspensorium, a sharp process. The upper process is its proximal part or head, the lower is its symplectic prolongation.

The middle part has two lobes, below, and behind; the upper of these afterwards gives off the opercular process, the lower is already scooped on its inside where it articulates with the next joint, the inter-hyal (*i.hy.*). This latter piece is a small pyriform segment, with its lesser end upwards and hooked inwards, for articulation with the hyomandibular. This is, so to speak, a supernumerary segment placed between the *antero-superior* pier and the *postero-inferior* arch. That arch is already composed of a main bar above, the cerato-hyal (*c.hy.*),—a thick rounded rod, and a short, almost globular segment below, the hypo-hyal (*h.hy.*); the two fit together by flat facets; the right and left hypo-hyals touch each other below. In front of and between these lower segments there is a tract of tissue which will harden into the basi-hyal (*b.hy.*).

The branchial arches (*br.*) are slender rods, bent in a sigmoid manner so as to form round in-turned hooks, above. The last (br^5.) is only one-fourth as large as the other

* MR. BALFOUR informs me that this bar is primarily continuous with the skull, and that after chondrification it is still unsegmented.

four, and is permanently arrested as the "inferior pharyngeal;" it is simply a short cerato-branchial.

The four well-developed rods are not yet segmented across into the normal pieces; they are oval in section, pointed above, and rounded below, where they articulate with the common basi-branchial (*b.br.*), which is one-third thicker than the arches. This conjugating rod is somewhat flat; it is thickest in front, where it fits by a rounded end between the hypo-hyals, and flat behind, where it projects beyond the arches.

Third Stage.—Young Lepidostei, $7\frac{1}{4}$ *to* 8 *lines long.*

In young individuals about two-thirds of an inch (16 to 17 millims.) long, the cartilage has become quite consistent, and some parts not chondrified in the last stage have become solid.

The head (Plate 30, figs. 5, 6) has straightened out considerably, and the basis cranii bulges below; but the sharp, recurved fold under the mid brain, where the fore and hind brain approximate, although a mere chink, is ineradicable.

The round and curiously mammillated snout is much smaller now, relatively; the notochord (*nc.*) has retreated considerably; the pituitary body (*py.*) is still separate from the infundibulum (*inf.*).

The azygous trabecular bar (figs. 7, 8, *i.tr.*) now shows itself in sections taken vertically through the head, but all the rest of the basal cartilage is far from the mid line. The notochord (*nc.*) is very large, and descends considerably beneath the swelling hind brain (figs. 5, 6, C^3.). Below the mouth and throat, the fore end of the mandible is seen in the *right* section (Plate 30, fig. 5, *mk.*); it contained more than half of the head above, and less than half below; thus that rod, and the rest of the post-orals (*hy.*, br^{1-4}.), are cut through a little on the right side of the middle. But in the *left* half (Plate 30, fig. 6), the median rods (*b.hy.*, br^{1-4}.) are brought into view, below; above, the junction of the trabecula with the palato-quadrate (*tr.*, *p.pg.*) is seen; this, however, had to be exposed by dissection; the sub-ocular space is seen as a crescentic gap with its convexity downwards.

The chondrocranium is figured as seen from above and below in a dissection of a somewhat larger specimen (8 lines long); it is much more perfect than in the last stage (Plate 30, figs. 3, 7, 8).

A full third of the cranial floor is membranous; the side walls are membranous in front, and are made by the auditory capsules behind; but a rudiment of the roof or "tegmen cranii" is now found, right and left.

The thick cranial notochord (*nc.*) is only half the length of the chondrocranium, now; it is somewhat moniliform, lessening by three successive stages, and is bent a little in this specimen to the right.

The narrow part is rounded at its end, and ascends but little into the clinoid fissure (Plate 30, fig. 5, *nc.*); a third part at least is not invested by the parachordal cartilage (*iv.*).

The huge so-called pituitary space (*py.*) is pyriform, has an indented outline behind, and is apiculate in front. The concave inner side of the basal bands embrace the notochord closely, and end behind in bevelled flaps; in front, where the last narrowing of the notochord takes place, they end almost transversely, but give off from their outer edge the trabecular outgrowths. They are quite confluent, externally, with the well-chondrified auditory capsules (*au.*). In their broad, proximal part the trabeculæ (*tr.*) are dilated, and are perforated by the internal carotid artery;* thence they converge steadily as scarcely arcuate bands, only one-third as large as their parachordal roots (*iv.*).

Their front confluent part is as long as their hinder separate part; and there the bands double their width, have a convex outline externally, and narrowing inwards at their extremity, are continuous then with the palato-quadrate bars (*p.pg.*). The front margin of these four bands is crenate, with three convexities, the middle enlargement being the largest; this is not, however, formed by the trabeculæ themselves, but by a pyriform wedge of newer cartilage, which has developed between and above them. This new element is the intertrabecula (*i.tr.*); in the last stage (Plate 30, fig. 3, *i.tr.*) it was merely composed of embryonic cartilage—a small, inconspicuous tract of tissue, lying between the dilated ends of the trabeculæ (*tr.*).

This new tract does not reach to the pituitary space, but already, in the upper view, can be seen projecting beyond the confluent paired bands (*tr.*, *p.pg.*). The simple, ovoidal form of the auditory capsules (*au.*) is now lost, for the semi-circular canals (*a.s.c.*, *h.s.c.*, *p.s.c.*) have developed greatly, and they have given the form of their curves and swellings to the cartilaginous capsule.

The floor of the sacculus is still largely membranous (fig. 7, *au.f.*); this circular fenestra is inside the centre of the floor; within, also, the capsule is not cartilaginous. Outside, the bulging of the horizontal canal (*h.s.c.*) has formed a rudiment of the "tegmen tympani" (fig. 7); this, however, is simply used to form the large oblong concavity for the hyomandibular (*hm.*), and never acquires any tympanic function.

The large cranial nerves have free course over the basal plate, and in front of and behind the auditory capsules they have only membrane to pass through; the space for these (Plate 30, figs. 7, 8, IX., X.) is seen to be very wide.

From the front of the auditory capsule cartilage is creeping along the superorbital region (fig. 8, *s.ob.*); this new tract is styliform, and at present only reaches one-third of the distance to the end of the chondrocranium. Below this rudiment, right and left, of the "tegmen cranii" the proximal part of each trabecula has developed an oblong facet of cartilage for articulation with the *pedicle* of the suspensorium (*pd.*); this is the first appearance of the paired "basipterygoid" processes of the basicranii. I take this to be not only the first appearance of these important processes in

* This passage is seen inside the superorbital cartilage (*s.ob.*); the line leading from the letters to this part in fig. 8 is not long enough.

the development of this particular skull, but also in the order of the types; in the Amphibia, Reptiles, Birds, and Mammals these processes are seldom absent.

The dorsal end of the suspensorium or mandibular pier has already become oblique; the true extremity is now lateral, and is the pedicle of the pier; this is an oblong tract or facet articulating with the basi-pterygoid face on the basal band.

The second part is the otic process (behind *pd.*); it is a subtriangular "ear" of cartilage, running backwards towards the pier of the hyoid arch (*hm.*), under the superorbital rudiment (*s.ob.*). Thence the suspensorium narrows gently, and a little behind the middle of the bar forms, on its outside, a jutting step; this is the gently concave quadrate hinge which articulates with the mandible (*mk.*).

The rest of the suspensorium lessens to one-half its hinder width, and is *f*-shaped, bending inwards at first and then outwards before it makes its last inward bend to join the trabecula (Plate 30, figs. 7, 8, *p.pg.*, *tr.*). The extent of the coalesced part is greater than the width of the bar; both that part and the fore part of the free bar belong, not to the proper pier of the mandible, but to the palato-maxillary arcade—it is the proper "ethmo-palatine." In the Tadpole of all, and the adult of most, Batrachia, it is not differentiated from the pterygoid band. The mandible (*mk.*) has already a flattish articular facet, an angular and a coronoid process; the main bar is gently arcuate, and lessens gradually to its distal end, which is rounded, and does not touch its fellow of the opposite side.

The hyoid arch is large and highly subdivided; it has now a large forwardly-projecting basal piece (Plate 30, fig. 8, *b.hy.*).

The pier is the hyomandibular (*hm.*), with its styloid symplectic fore-growth (*sy.*); this part is free, and not, like its serial homologue the pterygoid process of the suspensorium, concrescent with the bar in front of it. This hyoid pier is still three-fourths as large as the pier of the mandible; its dorsal condyle is large and rounded, its body is swollen behind, ready to form the "opercular process," and below this knob, on the inner side, it is scooped for articulation with the inter-hyal (*i.hy.*). Here, as in the *hyostylic* types of fishes, the hyoid arch is subdivided primarily into an antero-superior and a postero-inferior bar; but in this type, as in the Teleostei, the latter is subdivided again into three segments—the inter-hyal, the cerato-hyal, and the hypo-hyal (*i.hy.*, *c.hy.*, *h.hy.*).*

The inter-hyal (*i.hy.*) is a small, short, but thickish segment which articulates with the inner face of the hyomandibular (*hm.*) above, and with the cerato-hyal (*c.hy.*) below. The cerato-hyal is nearly as long as the mandible, and is twice as thick as its distal part; it is oval in section, rather pinched in at the middle, and rounded at both ends. The lower convex end fits into the shallow cavity on the top of the hypo-hyal

* In the Sturgeon and its congeners the symplectic is segmented off from the hyomandibular, and the same thing often occurs in the diminished and modified hyoid pier of the Batrachia, and even amongst some of the *Sauropsida*, as in the Chelonia (see 'On the Skull of *Chelone viridis*,' "Challenger" series, vol. i., part 5, plate 6, figs. 6, 6*a*).

(*h.hy.*), the thick, semi-globular, distal segment of the arch. The basal piece, *glosso-*vel *basi-hyal* (*b.hy.*), is wide, oblong, and three-fourths the height of the cerato-hyal; its rounded fore end is rather blunt; it is, in reality, a double bar, and its tissue is much lighter and more spongy than that of the side bars; its posterior end is doubly scooped for articulation with the hypo-hyals.

The branchial arches (Plate 30, fig. 8, *br'.*) are now beginning to divide across into four pieces on each side, namely, a pharyngo-, an epi-, a cerato-, and a hypo-branchial (see Plate 31, figs. 12, 13); a rod of cartilage of about the same thickness as the arches runs along the mid line, connecting them together; this is the basi-branchial (*b.br.*).

Transverse sections of a somewhat younger specimen ($7\frac{1}{4}$ lines long) show much that is instructive, and corroborate the observations made upon *dissected* embryos.

Section 1.—The first of these (Plate 31, fig. 1) is in front of the chondrocranium, through the fore part of the nasal capsule (*ol.*). The skin is very thick, and the mucous membrane of the nasal sac is composed of large columnar cells. The upper part is much flatter than the lower, in which three of the suctorial disks (*s.d.*) are seen in section.

Section 2.—The next section (Plate 31, fig. 2), is through the middle of the nasal sacs (*ol.*) and the fore-part of the hemispheres (C^{1a}.); here the lower face is less convex and the upper more so; the fore end of each trabecula (*c.tr.*) is cut through; it is a rounded projection, the rudiment of the free cornu.

Section 3.—The third section (Plate 31, fig. 3) is through the back of the nasal sacs (*ol.*), the first third of the cerebral hemispheres (C^{1a}.), and the solid coalesced end of the triple trabecular outgrowths of the basis cranii. The outline of the trabeculæ (*tr.*) is clearly seen below; but above, these bars—which are oval in section at this part and very thick—are confluent with an upper median mass, the intertrabecula (*i.tr.*); this is wider than the paired bars, fits in and on them, and rises over them as a dilated and concave floor to the membranous floor of the cranium.

Section 4.—The fourth section (Plate 31, fig. 4) is through the hemispheres (C^{1a}.) and barely misses the eye-ball (for *ol.* read *e.*). Here the fore end of the palato-quadrate cartilages (*p.pg.*) is cut through, where these bars run into the trabeculæ (*tr.*). The intertrabecula (*i.tr.*) is wider and flatter, and the shallow sulcus between the paired trabeculæ is gone; they together form a convex mass below, at this part. The section of the palatines would be circular, but the conjugational band is very thick, and obscures their real form.

Section 5.—The fifth section (Plate 31, fig. 5) runs through the fore part of the eye-balls (*e.*). This section is at the end of the intertrabecula (*i.tr.*), and the trabeculæ and palatine bars (*tr.*, *p.pg.*) are only half as large as in the last, and this section is seen to be oval, for the connecting cells are much reduced in quantity.

Section 6.—The sixth section (Plate 31, fig. 6), a little farther back, shows an evident fissure between the trabeculæ (*tr.*), which are now flatter, like bricks, and the connecting band is so thin as almost to set the palatine band (*p.pg.*) free.

Section 7.—Here (Plate 31, fig. 7) those bands (*p.pg.*) are free, and the trabeculæ (*tr.*) look like two flat, partly confluent bricks, gently bent round the base of the membrano-cranium. The section of the palatine bars, now very slender, is circular.

Section 8.—In this section (Plate 31, fig. 8) the eye (*e.*) is cut through its middle, and the mandible, very short as yet, has come into view; here, of course, the mouth cavity (*m.*) is shown. The pineal body (*pnl.*) and the fore part of the mid brain can just be seen, as well as the back part of the hemisphere (C^{1a}.), running into the thalamencephalon below. The trabeculæ (*tr.*) do not now follow the convexity of the membrano-cranium, but are flat and horizontally placed; they are distinct here, and oval in section. The palatine bars (*p.pg.*) are now round in section, and are more than twice their own diameter from the trabeculæ. Below the mouth cavity (*m.*) the mandibles (*mk.*) are cut through obliquely; they are rounded rods, similar to the palatines at the same part.

Section 9.—The ninth section (Plate 31, fig. 9) is through the mid brain (C^2.) and the thalamencephalon (C^1.). The trabeculæ (*tr.*) are now nearly cylindrical, and are a distance apart equal to twice their own thickness. Between them a thin lamina of bone is cut through; this is the parasphenoid (*pa.s.*). Outside the oral cavity (*m.*) the palato-quadrate cartilages (*p.pg.*) are seen to be flattened and concavo-convex, the convex side being turned inwards. On each side, below the mouth, the mandibles (*mk.*) are cut through obliquely. Above, in the superorbital region, the rudiment of the tegmen cranii is seen as a narrow band of cartilage—flat outside and convex within.

Section 10.—In the next section (Plate 31, fig. 10) the swelling mid brain (C^2.) reaches the superorbital bands on each side; the trabeculæ (*tr.*) are nearly twice as far apart as in the last, and are quite circular in section. Between and below them the parasphenoid (*pa.s.*) is twice as wide as in the last. This section shows the articular end of the mandible (*ar.c.*) joined to the hinge on the quadrate end (*q.*) of the palato-quadrate pier; this part is now high, flattened, and convexo-concave, with the concavity on the outside.

Section 11.—This is through the widest part of the mid brain (Plate 31, fig. 11, C^2.), the thalamencephalon (C^1.), the infundibulum (*inf.*), and the distinct pituitary body (*py.*). The superorbital bands are flatter and nearly vertical in position; the trabeculæ (*tr.*) are now furthest from the mid line; the parasphenoid bone is still visible below the pituitary body; and the convexo-concave quadrates (*q.*) are now cut through *behind* the mandible at the mid line below the mouth (*m.*). The tongue (*tg.*) is cut through in front of its cartilaginous core.

Section 12.—The next slice is through the hind brain (Plate 31, fig. 12, C^3.), the front part of the auditory capsule (*vb.*), and the fore end of the notochord (*nc.*). On each side of the hind brain there is a large mass of nerve-cells, the rudiment of the ganglia of the trigeminal and facial nerves (V., VII.).

The investing mass (*iv.*), wide up to its fore end, and not embracing the ascending apex of the notochord (*nc.*), is a rather thick plate of cartilage; the inner edge of each

slab does not touch the notochord at this part. These basal bands are quite confluent with the auditory capsules, which are very solid on their outer side, but remain membranous to a considerable extent on the inner.

The anterior semicircular canal (*a.s.c.*) is cut through, and also the main cavity (*vb.*) with the horizontal canal opening into it; this canal bulges out the capsule, and under the "tegmen" thus formed we see the hyomandibular (*hm.*) as a continuous ray, thick and bulbous, below. Below it, at a little distance, the joint being further back, we see the second segment, or inter-hyal (*i.hy*); it is short and semi-elliptical, with a truncated end below. That end articulates with the rounded top of the phalangiform cerato-hyal (*c.hy.*), which is between it and the hypo-hyal; this latter segment was in front of this section (see Plate 30, fig. 8, *h.hy.*)

The foremost branchial arch is cut through near its ventral end, through the lower part of the cerato-branchial, as well as the distil and basal pieces (*c.br.*, *h.br.*, *b.br.*); these parts lie behind the tongue.

Section 13.—The next section (Plate 31, fig. 13) is behind the junction of the auditory capsules with the basal plates. These latter are here very massive, and almost square; the notochord (*nc.*) between them is very large; the ganglia of the vagus and glosso-pharyngeal (IX., X.) fill up much of the space below, between these bars and the capsules; but above, the open space is for the auditory nerve (VIII.). The anterior and posterior canals (*p.s.c.*) are cut through at their junction, and the horizontal canal where it opens behind into the vestibule (*vb.*). The hyomandibular (*hm.*) is severed behind its upper, or articular head, and that is the only part of the hyoid arch which comes into view here. The lower part of two of the branchial arches (*br.*) is cut through close above the heart (*h.*).

Bony matter is forming in the opercular fold, a growth from the hyoid region, and its great size, wrapping over the gill-arches and heart (*h.*), is well shown.

Section 14.—In this section (Plate 31, fig. 14*), the auditory capsule is seen to approach the investing mass (*iv.*) behind the large membranous deficiency in the inner wall. The basal plates cut through are here at their thickest part, and the posterior canal (*p.s.c.*) is most of it seen, as it becomes bulbous below. Here the notochord (*nc.*) has almost its full (*spinal*) thickness; the hyomandibular is cut through in its hinder part, or "opercular process;" only the upper part of this section is figured.

Section 15.—This (Plate 31, fig. 15*), which is behind the ear-capsule, shows that the occipital ring is still very incomplete, only the basal and lateral parts (*e.o.*) being developed. The basal cartilage (*iv.*) is thinning out towards the first vertebra; the pharyngo-branchial of the last functional arch (*p.br.*) and its gills (*br.p.*) are displayed; the notochord (*nc.*) is now full-sized. A comparison of these sections with the upper and lower views of the chondrocranium at this stage (Plate 30, figs. 7, 8) will make all plain.

* Fig. 14 is lettered 15, and fig. 15, 14 by mistake.

Fourth Stage.—Young Lepidosteus, $11\frac{1}{2}$ *to* $12\frac{1}{2}$ *lines long: average size* 1 *inch.*

In these, the largest of those reared by Professor AGASSIZ and Mr. GARMAN, the chondrocranium is perfect; the occipital arch is beginning to ossify, and the investing bones are very numerous and quite distinct.

The cranium at this stage (Plate 32) corresponds very closely with that of a young Sturgeon *five inches* long, but has much larger membranous tracts, and is altogether a much lighter structure; in having rudimentary basi- and ex-occipital bony centres, it has already gone beyond the skull of an adult Sturgeon.

The fissure between the fore and hind brain (Plate 32, fig. 4, C^1., C^3.) is very distinct, and reaches to the base of the mid brain (C^2.); but there is no "posterior clinoid wall," such as would exist and be very massive in the skull of an embryo Sauropsidan or Mammal at the same stage.

Already the notochord (Plate 32, fig. 4, *nc.*) has retreated to a considerable distance behind the pituitary body (*py.*), which is now an appendage to the infundibulum (*inf.*); the brain well fills the whole cranial cavity up to this stage, but the hemispheres (C^{1a}.) are relatively very small.

Another thing to be noticed is this, namely, that the *pre-cerebral* growth of cartilage is almost as long as the whole cranial cavity, although it is only a fraction of the length to which it will attain. At first sight it might be thought that the mesocephalic flexure was gone, but the up-throwing of the mid brain, and the meeting of the fore and hind brain, show that the bend is very large and very sharp *at one point.* The four faces of the skull are all largely membranous, and but for the notochord (*nc.*), the floor would be open along nearly its whole length, for the cartilage only closes in at the mid line beneath the front end of the hemispheres and the olfactory lobes (C^{1a}., C^{1b}.). The thick cranial notochord (*nc.*) is receiving a bony investment between the thin, post-auditory ends of the investing mass (*iv.*); this will be seen better in the transverse sections (Plate 33). The fore ends of the basal bars (figs. 2, 3, *iv.*) diverge from the notochord (*nc.*) some distance behind its apex; in the middle part they are completely confluent with the auditory sacs.

The narrowed, diverging bars that retreat from, and then shoot on far in front of the notochord, are the trabeculæ (*tr.*); they approximate gently, and their interspace in front is sharply pointed. But the trabeculæ have not merely approximated, they are united together by the intertrabecular wedge (see Plate 31, figs. 7, 8, *i.tr.*); and this has now become a large rod, running forwards to the end of the narrow snout.

Outside this thick rod, but little of which is formed by the lateral bars, those bars grow externally into a large lanceolate leaf of cartilage, which reaches right and left nearly to the small, *distant* nasal sacs (fig. 5, *ol.*). These peculiarly *Acipenserine* outgrowths of the trabeculæ are the familiar "cornua" (*c.tr.*) curiously modified; both ends of each leafy growth are free, as rounded ears of cartilage; on the inside there is a sulcus, deepest, on both surfaces, between each cornu and the coalesced bars in the middle.

There is a squarish ear of cartilage on each side the pituitary body, growing from the trabeculæ, and looking outwards and forwards; these are the "basi-pterygoid processes" (*b.pg.*), so familiar to us in the Amniota; to these the pedicles of the suspensorium (*pd.*) are articulated. Behind these the auditory capsules are seen as very large masses, completely confluent with the chondrocranium. Below (Plate 32, fig. 2, *vb.*), the vestibule forms an almost hemispherial projection; this is caused by the sacculus, which contains the otolith (fig. 3, *ot.*).

Behind this there is a lesser eminence caused by the ampulla of the posterior canal (*p.s.c.*), between it and the larger cavity we see a shallow fossa. On the outside of this fossa the capsule projects, where it contains the horizontal canal (*h.s.c.*), and under this projection there is an oblong articular cavity for the hyomandibular.

Outside this, and between it and the superorbital band (*s.ob.c.*), there is a rounded projection. This corresponds with the lateral pre-auditory mass seen in Teleostei and ossified as the so-called post-frontal—my sphenotic ("On the Salmon's Skull," Phil. Trans., 1873, Plate 7, figs. 1–3).

Above (Plate 32, figs. 1, 5, *sp.o.*, *a.s.c.*, *h.s.c.*, *p.s.c.*), the outline of the large ear capsules is sinuous, the sinuosities being caused by the bulgings of the horizontal and posterior canals, and by the sphenotic process. Between the capsules, above, the tegmen cranii (*s.o.*, *t.cr.*) is developed both over the occipital and the post-sphenoidal regions. This roof is rather pointed behind, over the foramen magnum, and has an evenly concave margin in front; there it forms the hinder boundary of the large fontanelle (*fo.*), which is a short oval, emarginate in its narrow fore end. In front of the fontanelle there is a considerable *ethmoidal tegmen* (*t.cr.*), which covers the olfactory lobes and the small hemispheres (Plate 32, figs. 4, 5, C^{1a}., C^{1b}.); this is pointed behind in the middle, and laterally runs into the narrow arcuate superorbital band. The sides of the skull are oblique, the roof being more than thrice the width of the floor in the orbital region; these sides are mainly membranous; thus the orbito-sphenoidal cartilages are only represented by so much of the superorbital bands as belong to their territory; the alisphenoidal cartilage is merely so much of the chondrocranium as projects beyond the auditory capsule, laterally, between the basipterygoid and the sphenotic processes (*b.pg.*, *sp.o.*).

The small nasal capsules (fig. 5, *ol.*) have no separate cartilaginous roof; they are carried to the front of the snout.

The suspensorium of the mandible has retained its *primary* continuity with the ethmo-palatine cartilage, so that it is still a palato-quadrate (Plate 32, fig. 2, *p.pg.*, *pd.*); but this is quite free now from the other primary connexion, namely, that with the trabecula (*tr.*). This large arch, with its pier, foregrowth, and free mandibular bar, has undergone a similar lengthening to that of the cranium.

The pier or suspensorium is a large, oblongo-arcuate plate, ending in front in an oval sub-convex condyle, and a long, terete, pterygo-palatine process; this latter is consider-

ably longer than the main part, and reaches as far forwards as the cornu trabeculæ (Plate 32, figs. 1, 2, *p.pg.*, *c.tr.*); it is slightly arcuate.

The main part of the suspensorium has a thick convex lower, and a sharp concave upper, margin. The upper edge has a convex enlargement behind. This is the rounded pedicle, which articulates with the basipterygoid process of the trabecula (*pd.*, *b.pg.*). The lower margin becomes concave towards the end; a postero-external, triangular process—the otic process—finishes the dorsal end of the suspensorium. The sub-convex, oval condyle (*q.c.*) looks forward and outward, and fits into the scooped hinder face of the articular region of the free mandible. Above its articular concavity the mandible sends forwards a large rounded ear of cartilage, convex outside (Plate 32, fig. 1, *cr.c.*) and concave within (fig. 2, *cr.c.*); this is the coronoid process of the mandible. The angular process is a free rounded spur below and behind the articular concavity. The rest of the rod (*mk.*) is terete, and almost straight; it is only slightly arched upwards and reaches nearly to the end of the snout.

The hyoid arch (Plate 32, figs. 1 and 2) has a pier which is curiously and suggestively like the suspensorium of the mandible; but, already, it is relatively much less, being now about half as large. It has a pedicle, a free posterior process, a fore-growing rounded rod, and an articular facet for the free, inferior arch; the only difference, here, is the absence of any *borrowed* addition at the fore end, such as the pterygoid cartilage has in the concrescent palatine.

The *pedicle* of the hyoid pier (*hm.*) is the oblong, articular head, fitting inside the oblong concavity under the auditory "tegmen;" it has no definite neck.

The free posterior process (*op.p.*) is for the opercular bone; it is short and rounded. The fore-growing rounded rod is the "symplectic" region (*sy.*); it is terete, gently curved downwards, blunt at its fore end and enlarged near its origin; it lies anteriorly behind (under) the convex edge of the suspensorium. The body of the hyomandibular is gently bilobate and fenestrate in the middle (*hm.f.*); the articular facet for the "inter-hyal" (fig. 6, *i.hy.*) is a scooping between the two convexities of the hind margin (Plate 32, fig. 2).

The rest of the hyoid arch is not in one piece like the mandible, but in *three*, and these have, also, a large double median bar conjugating them. The first of these is a small, unciform segment of cartilage, the inter-hyal (fig. 6, *i.hy.*); it is articulated to the inner face of the hyomandibular by its hooked end, obliquely, and obliquely also to the top of the cerato-hyal by its base. The latter (*c.hy.*) is half the length and twice the thickness of the mandible; it is a rounded rod, swollen near the top, and then thickened gradually to its distal end. All but the top and lower concave face is ossified.

The distal concave end is articulated to the top of a globular segment—the hypo-hyal (*h.hy.*); this is not ossified. The right and left segments fit into a pair of concavities on the hind face of the glossal piece, or basihyal (*b.hy.*). This is tongue-shaped, the sides are parallel, the fore end rounded; it is moderately thick, is essentially

double, and is as long as the cerato-hyal. The subdivided, ossifying branchial arches will be described in the next stage.

The uniformity of the rapidly elongating intertrabecula is shown in the vertical section of the skull (Plate 32, fig. 4, *i.tr.*). The three trabeculæ are shown inside the lengthening snout, with its four rows of mucous glands in a second upper view (Plate 32, fig. 5); and in it, also, the position and relation of the sense-capsules and brain are displayed, and also how that the tegmen cranii (*t.cr.*) leaves the large mid brain (C^2.) unprotected.

A partial view of the chondrocranium, namely, the floor, from its upper face up to the end of the cranial cavity (Plate 32, fig. 3) shows the huge notochord (*nc.*), whose bony sheath is incomplete above, and the fore end of which is free, and but little attenuated; that part is curved but little upwards (see Plate 32, fig. 4). The fusion of the basal bands and auditory capsules is shown to be perfect, and the cupped tracts for the ampulla of the posterior canal (*p.s.c.*) and for the sacculus (*vb.*) are also seen. In front of these, on each side of the diverging parachordals—now to be called trabeculæ (*tr.*)—the basipterygoid peduncles (*b.pg.*) are shown. In the emargination behind these, in the fore part of the ear-capsules and in the occipital ring, thin films of bony matter are forming, which will become the alisphenoids, prootics, and exoccipitals; these will be shown better in the sections. The huge lanceolate pituitary fenestra (*py.*) is floored by the parasphenoid (*pa.s.*), which wedges in, in front, between the converging trabeculæ. In front of that part the chondrocranium is complete. The olfactory nerves (I.) escape from the bulbs (Plate 32, figs. 4, 5, C^{1b}.) and run along to the distant nasal sacs (*ol.*) between the intertrabecula and cornua trabeculæ in the deep groove between them above. The nasal branch of the ophthalmic (5′) runs forwards outside these. Some of the bony plates are shown on the chondrocranium; the foremost of these is the first of the *maxillary chain* (figs. 1, 2, *mx′.*); and on the palato-pterygoid there are three "parastoses," namely: the palatine, pterygoid, and mesopterygoid (Plate 32, figs. 1, 2, *pa′.*, *pg.*, *ms.pg.*).

Transversely vertical sections show much that is instructive in this stage also (see Plate 33, figs. 1–13).

Section 1.—In this (Plate 33, fig. 1) the fore end of the long face is seen to be convex above and somewhat concave below. The skin is very thick and glandular; the nasal sacs (*ol.*) are simple pouches, with a thick epithelium, the tissue beneath the skin has now become osseous; in this way we get the premaxillaries, nasals, maxillaries, palatines, &c.; the plates directly over the nasal sacs are the nasals, and the palatine part of the premaxillaries is shown below the sacs. In this section we see the fore end of the prenasal cartilage or intertrabecula (*i.tr.*); it is a long oval in section, with the narrow part below and the sides compressed.

Section 2.—Here (Plate 33, fig. 2) we have the prenasal (*i.tr.*) cut through behind the nasal sacs; palatine teeth attached to bony laminæ (*pa′.*) are seen below, and similar

bony tracts (*p.ob.*) are seen, right and left above, enclosing the olfactory nerve (I.). Here the cartilage (*i.tr.*) is alate, each sharp wing being nearer the base than the top.

Section 3.—In this (Plate 33, fig. 3) the parts to be described are numerous, for the cornua trabeculæ (*c.tr.*) are cut through, and also the palato-quadrate (*p.pg.*) near its fore end. The intertrabecula (*i.tr.*) is oval in section, but it grows out, right and left, into wings, which thicken towards their outer edge and are as wide as the median bar; these are the cornua trabeculæ (*c.tr.*). Under their rounded end we see a small oval section of cartilage placed obliquely; this is the palato-quadrate (*p.pg.*). The fossa over each cornu trabeculæ is more scooped than that beneath it; in this lies the olfactory nerve (I.).

Beneath the intertrabecula, and following its curve, there is a thin lamina of bone; this is the parasphenoid; the oblique laminæ right and left of this are the vomers. The palatines (*pa'.*) are seen in the submarginal ridge, and one of the maxillary chain of bones (*mx'.*) in the lesser, outer ridge. Above, some of the superior (or ethmo-nasal, *et.n.*) and supero-lateral (or preorbital, *p.ob.*) scutes are cut through; the former protect the olfactory nerves (I.).

Part of this section (fig. 3A) is separate from the rest; it is through the lower jaw, in front of the tongue.

Here MECKEL'S cartilage (*mk.*) has a short oval section; outside it we see the dentary (*d.*) as a larger and a lesser lamina.

Section 4.—This (Plate 33, fig. 4) is behind the angle of the mouth, and close in front of the cranial cavity, where the three bars (*i.tr.*, *c.tr.*) are thickest. The middle part is one-half higher than in the last section, and is broader above and below. The side bars (*c.tr.*) are twice as thick here, and are shorter, and upturned; the olfactory nerve (I.) grooves both the bars, and is more than half enclosed in cartilage. Under these thick rounded wings each palato-quadrate (*p.pg.*) is seen; it is twice as thick as in the last section, is circular, and is its own width below the trabecular cornu.

As this is close behind the gape the mandible is in two sections; the upper is small—it is the fore end of the coronoid process; at a good distance below this part the main rod (*mk.*) is severed; it is oval, with the narrow end above. Bony laminæ belonging to the preorbital series of scutes are seen supero-laterally; below the intertrabeculæ the parasphenoid (*pa.s.*) is shown; a hooked, zigzag line of bone is seen propping up the palato-quadrate cartilage; this is the pterygoid, whilst outside the mandible the dentary (*d.*) is visible.

Section 5.—This (Plate 33, fig. 5) was made through the fore part of the hemispheres (C^{1a}.) and of the tegmen cranii. The base is formed almost entirely by the trabeculæ (*tr.*) for the middle bar dies out in this region; here they are at their thickest part; they form a crescentic mass, the horns of which grow upwards and a little outwards as the lateral ethmoidal wall. These walls pass above into the convex roof; there is a superorbital enlargement where these thickish laminæ pass into each other.

The palato-quadrate cartilages (*p.pg.*) are lesser again, flattened obliquely, and are still further from the basal bars. Behind the angle of the mouth the mandible thickens rapidly; this part (*ar.c.*) shows a section oblique and sub-reniform, close in front of the articular condyle. The large mouth-cavity (*m.*) is partly filled here with a transversely oval mass—the tongue; it has a large *double* core of a soft spongy kind of cartilage; this is the exceptionally symmetrical basi-hyal (*b.hy.*).

The same kind of surface bones are cut through above; the outer film is a superorbital (*s.ob.*)—a continuation of the same chain as the preorbitals; and the inner piece is the pointed fore end of the frontal (*f.*). The pterygoids (*pg.*) are still in section, but the mandible is cut through behind its splints.

Section 6.—The next section (Plate 33, fig. 6) is through the middle of the eye-ball (*e.*), and through the hinder wide part of the hemispheres (C^{1a}.). Here the cranium is largely membranous, for the only cartilages cut through are the superorbitals (*s.ob.c.*), mere bands running superolaterally, and the trabeculæ below. The latter (*tr.*) are just distinct at this point, and are brick-shaped—a little turned up at their outer ends. Thus at this part we have the fore end of the great fontanelle (see Plate 32, fig. 1, *fo.*), and the wide orbito-sphenoidal fenestra (fig. 2, *os.f.*).

The quadrate region (*p.pg.*) is cut through here, behind the hinge of the mandible; this is still faced on the inside by the pterygoid (*pg.*), whilst another film of bone is cut through above, namely, the mesopterygoid (*ms.pg.*). Above, the frontals (*f.*) are seen in section, and below, the tongue and basi-hyal (*b.hy.*).

Section 7.—This (Plate 33, fig. 7) is post-orbital, and is through the mid brain (C^2.), and the thalamencephalon (C^1.), near the pituitary body.

The trabeculæ (*tr.*) are very small, nearly circular in section, and at their greatest distance apart. The flattened superorbital bands (*s.ob.c.*) are thrown to the side of the membrano-cranium, which is at its weakest point here. The quadrate (*q.*), which was thin above and thick below in the last, is now thick above and thin below; the long pterygoid is still on its inside, and below its out-turned thin edge a small round rod of cartilage is seen: this is the symplectic (*sy.*).

In the root of the tongue there are three cartilages cut through, the middle bar is nearly circular, the others are flattened; these are the basi-branchial and the first hypo-branchials (*b.br.*, *h.br.*). In a fold outside and below these, a thicker round rod is seen; this is the cerato-hyal (*c.hy.*). Protecting the pituitary body, the parasphenoid (*pa.s.*) has here widened out considerably; for a short space, shown in this and the next section, the roof shows scarcely any osteoblasts.

Section 8.—This section (Plate 33, fig. 8) is through the fore part of the auditory capsules and the widest part of the mid brain (C^2.), where it turns down to join the hind brain. The anterior canal (*a.s.c.*) is cut through; here the capsule (*au.*) is imperfect within, and is beginning to ossify as the prootic. The investing mass (*iv.*) is cut through where it is shooting out into the trabeculæ, and the bands are wide apart. The superorbital band has now passed into the antero-superior angle of the auditory

capsule. The pharyngeal cavity is open below, for here the great opercular fold is cut through; in it bony plates (*op.*) are forming; in its upper part the root of the symplectic (*sy.*) is severed, and below that a much larger bar with an ectosteal sheath; this is the cerato-hyal (*c.hy.*); below, the fore part of the heart (*h.*) is cut through, and above and across it the basal, distal, and cornual elements of one or two of the middle branchial arches (*b.br.*, *h.cr.*, *c.br.*). Here the parasphenoid (*pa.s.*) is of great width, undergirding not only the open basal fontanelle, but the basal plates also. The fore part of the Gasserian ganglion (5) is cut through.

Section 9.—This (Plate 33, fig. 9) is through the widest part of the hind brain (C^3.), and behind the fontanelle, for here we have the hind "tegmen" (*t.cr.*), as a thinnish layer of roof-cartilage, passing externally into the auditory capsules. At this part there is a thick band of cartilage on the inner side, in front of the large "meatus internus." Here the large ampulla of the anterior canal (*a.s.c.*) and the beginning of the horizontal canal are exposed, and outside it there is a ledge—tegmen tympani—with which the hyomandibular (*hm.*) is continuous. This is a flat cartilage; the whole of the hyoid pier is relatively small in this type.

Here the notochord is cut through, where it is enclosed by the broad, fore margin of the investing mass (*iv.*), which thins out, and curves outwards and upwards, to join the capsule. The opercular fold (*op.*) is cut through behind the lower part of the hyoid arch, which is projected forwards; the branchials (*br.*) are similar to the last, but further back in the series, and the heart (*h.*) is now cut across at its fore part.

There are several bony plates cut through in this, viz.: parietal, squamosal, opercular (*op.*).

Section 10.—Here (Plate 33, fig. 10) only the upper or main part is figured; it shows a section of the middle or widest part of the auditory capsule, where the inner wall is membranous. The anterior canal (*a.s.c.*) is cut through close to its junction with the posterior, and also the horizontal canal (*h.s.c.*) with the subdivisions of the vestibule (*vb.*). This section is behind the junction of the capsule with the investing mass (*iv.*), and shows the ganglion of the 7th and 8th nerves (VII., VIII.). The flat hyomandibular (*hm.*) is still in section, but behind its articular head; the broad parasphenoid (*pa.s.*), and the outer bony plates, are similar to those of the last section.

Section 11.—This (Plate 33, fig. 11) shows the hind part of the auditory capsule; the whole course of the posterior canal (*p.s.c.*) is seen through this back wall of cartilage. Here the capsules are some distance from the investing mass (*iv.*); above, the roof (*t.cr.*) has become deficient again, and at this part the hyomandibular (*hm.*) is cut through some distance below the condyle, and in this specimen a film of bone is seen investing the cartilage. The large notochord (*nc.*) has also a sheath of bone, and under each basal bar there is a section of the forked hinder part of the parasphenoid (*pa.s.*). One of the branchial arches (? the third) is seen in its whole extent (*p.br.*, *e.br.*, *c.br.*, *h.br.*, *b.br.*).

Section 12.—In this section (Plate 33, fig. 12) the occipital arch (*e.o.*) is cut through a

little behind its upper part, and quite behind the auditory capsules. Here the 9th and 10th nerves and their ganglia (IX., X.) are laid bare, and the heart (*h.*) is cut through at its thickest part. The investing mass has become narrow and hour-glass shaped in section; it sends upwards a cartilage which thins out gradually upwards; this is the exoccipital (*e.o.*), which becomes supraoccipital above. The exoccipital bones are forming as embracing ectostoses; the notochord has its sheath, the rudiment of the basioccipital (*b.o.*), and under the investing mass the parasphenoidal forks are seen. Here there is one pharyngo-branchial (*p.br.*) and the distal parts of two or three arches, with the basal piece (*b.br.*) lying over the heart (*h.*).

Section 13.—This last section (Plate 33, fig. 13) is close in front of the first vertebra; it catches the last pharyngo-branchial (for *h.br.* read *p.br.*), and shows some pharyngeal teeth. Only half the arch comes in here, but it shows well the outer and inner laminæ of the exoccipital bone (*e.o.*). Here the notochordal bony sheath (*nc.*, *b.o.*) is thicker, and the splintery ends of the parasphenoid narrower than in the last section.

In the last three sections bony laminæ are forming beneath the skin; these and their relations will be better understood by reference to the figures and descriptions of more advanced stages.

Fifth Stage.—Young Lepidostei 2 *to* 2½ *inches long.*

In this stage the skull is rapidly acquiring its permanent character (Plate 34, figs. 1, 2); the rostral part is now twice as long as the cranial cavity; in the last the pre-cranial part was not quite so long as the cranial.

This is mainly due to the growth of the intertrabecula (*i.tr.*), which already is considerably more than twice as long as the very long cornua (*c.tr.*).

The endocranium is now in this specimen (which is 2 inches long) nearly as perfect as it will be; the upper fontanelle (*fo.*) is a short ellipse, with the long diameter axial; it is relatively much less, through the growth of the tegmen cranii (*t.cr.*), fore and aft. The whole endocranium may be said to be pyriform, with an extremely long stalk; the "nose" of the *pear* is represented by the basioccipital (*b.o.*). The occipito-auditory region is semicircular above, with an apiculation over the foramen magnum; the orbital region is suddenly narrowed, and this gently lessens into the ethmoidal, which as gently becomes rostral, and the rostrum slowly lessens to its fore end, where it has two small wings. Near its root, however, it has two large wings—these are the cornua trabeculæ (*c.tr.*). The floor of the skull is still largely open (fig. 3), and the sides are occupied by the large orbital fenestræ (*os.f.*). The sheath of the notochord (*nc.*) is most completely ossified below; above (fig. 3), it is still membranous in front; the bony sheath is the basioccipital (*b.o.*); it runs a little, right and left, into the basal cartilage.

The auditory capsules are completely confluent with the chondrocranium; and their canals (*a.s.c.*, *h.s.c.*, *p.s.c.*) are to be seen through the cartilaginous wall. Above, the even form of the skull is not much altered by the canals within; below, the succulus

(fig. 2, *vb.*) largely swells the vestibular region; the form of this cavity is a short oval (figs. 2 and 3, *vb.*). The condition of the hind skull is best studied from above, in a preparation of the base (fig. 3); here the exoccipitals (*e.o.*) are seen to be forming broad borders of bone to the cartilage of the arch, and these are approaching the cephalostyle (basioccipital, *b.o.*).

Further forwards, in the angle between the capsule and the basal plate, under the Gasserian ganglion, the cartilage is being ossified as a prootic (*pr.o.*), and the wider wings which stand out from the front of the capsule are becoming the sphenotics (*sp.o.*). Also, still further forwards, the lower wings or basipterygoids (*b.pg.*) are getting a coating of bone; this ectostosis runs upwards into the side wall, in front of the capsule—it is the alisphenoid (*al.s.*).

In front of these last wings the trabeculæ (*tr.*) become bent, first outwards and then inwards, ready to join the median bar (*i.tr.*). They are rounded, solid rods. The basal fontanelle is now divided across, near its hinder end, by a narrow band, which is cartilaginous at its roots and fibrous in the middle; this is the *late* and feeble "post-pituitary wall" (*p.cl.*)—here a mere *bridge*.

The small triangular space behind is the posterior basi-cranial fontanelle (*p.b.c.f.*); the large, pinched, pyriform space in front is the pituitary space (*py.*) or anterior basi-cranial fontanelle. Its narrow anterior third runs up to the intertrabecula (*i.tr.*), which goes further back than the ethmoidal wall (*l.eth.*), and is, indeed, the rudiment of the "perpendicular ethmoid." Infero-laterally, the ethmoidal wall (Plate 34, fig. 2) is very restricted, for the orbito-sphenoidal fenestral (*os.f.*) is of great length, being extended equally in front of and behind the optic nerve (II.). But above (fig. 1, *t.cr.*) the tegmen cranii, in front, is as large as the long oval fontanella (*fo.*); behind that space the spheno-occipital tegmen is one-half longer, axially, and twice as wide across.

The three confluent trabecular bars combine to close in the fore part of the cranial cavity (Plate 34, figs. 1 and 3), only leaving an opening right and left for the long olfactory nerves (I.). When they have escaped from the skull they lie for the hinder half of their course in a deep rounded sulcus between the cornual extensions of the trabeculæ (*c.tr.*) and the huge middle bar (*i.tr.*). The three bars are at first nearly of the same width; the cornua are rounded where they first project as longitudinal wings, but they soon become narrow rods, and end in a pointed manner behind the middle of the pre-cranial region. Thence the intertrabecula is a gently compressed rod, only slowly lessening forwards, and ending as a slightly winged lobe in the end of the beak.

The first and second visceral arches (Plate 34, fig. 4) are elongated forwards like the skull, but the "pier" of the hyoid arch (*hm.*, *sy.*) is less than half the size now of the mandibular suspensorium (*p.pg.*, *pd.*). I have shown these with their splints attached as seen from above (Plate 34, fig. 1) and from below (fig. 2); also without the "parostoses" from their inner side (fig. 4). Their intrinsic bony centres or "ectostoses" are now clearly seen, but they are very small in proportion to the cartilage in which they

appear. The suspensorium and its free bar reach from the auditory region to a small distance behind the end of the snout; these cartilages, moreover, largely overlap each other; end to end, they would be considerably longer than the entire skull. The quadrate hinge (*q.c.*) is opposite the point where the olfactory nerves (I.) emerge, a little in front of the cranial cavity. The dorsal end of the suspensorium is bilobate; the pedicle (*pd.*) is an oblong, oblique facet, looking backwards and inwards, and articulating with a similar facet on the basipterygoid (*b.pg.*); the outer lobe is free; it is the triangular otic process (*ot.p.*); it reaches almost to the ear-capsule, but is too short to articulate with it. The main part of the suspensorium runs from these hind lobes to the quadrate hinge (*q.c.*); the inner margin is first hollow and then arched; the arch runs along the free anterior process; that edge is sharp. The outer edge is thick and ribbed on its inner face (Plate 34, figs. 2, 4); it is nearly parallel with the upper, being convex behind and concave in front. The width of this large plate is equal to half its length, and it is very elegantly sigmoid.

The quadrate hinge (*q.c.*) is a small oblong saddle, the main direction of which is forwards and a little downwards; it is convex outwardly, but has a rising inner crest (Plate 34, fig. 4), which fits closely to the articular condyle (*ar.c.*). Beyond the hinge the pterygo-palatine bar is first half as wide as its root, and then losing its inner crest, it becomes a rounded, straight, slender style, which ends very close to the point of the cornu trabeculæ (Plate 34, fig. 1, *p.pg.*, *c.tr.*).

The lower or inner face of the suspensorium is gently convex; the upper or outer face, gently concave. On the convex inner face there is a large splint-bone — the pterygoid (Plate 34, fig. 2, *pg.*); it covers more than half of the broad part of the cartilage—its antero-superior part. For some distance in front of the quadrate condyle it is continued forwards, undiminished in size; it then lessens gradually into a pointed style, which runs parallel with, and a little on the outside of, the rostrum (*i.tr.*) for three-fifths of its length.

A very narrow dentigerous bone underlies the narrow fore half of the pterygoid, and then goes beyond it up to the premaxillary, or nearly to the end of the snout. It is rather broadened in its diverging hind part, and then the right and left bones gently converge forwards; these are the *parosteal* palatines (*pa'.*).

Along the inner edge of the suspensorium there is a narrow, thin, falcate splint, which reaches from the top of the broad part to the neck of the pedicle; this is the "mesopterygoid" (*ms.pg.*). The front of the neck of the pedicle is ossified as a small ectosteal patch; this is the "metapterygoid" (*mt.pg.*). The neck of the quadrate condyle also is ossified; this is the small quadrate ectostosis (*q.*).

From the dilated end of the intertrabecula (Plate 5, fig. 2, *i.tr.*) to the fore end of the palato-quadrate styles, there is an extremely delicate pair of bony threads; these are the vomers (*v.*). In their hinder third these bones underlie the styloid end of a bone more than twice their breadth; this is the parasphenoid (*pa.s.*); it is carinate below, widening as it approaches the basis cranii; it then narrows till it nearly reaches

the optic nerve (for I. read II.); thence it widens, loses its keel, and becomes grooved along its middle below. This bone then trebles its width, and sends out two pairs of angular projections, the lesser to support the basipterygoid processes (*b.pg.*), and the larger farther back to support the vestibular swellings of the ear-capsules (*vb.*). The bone then becomes divided into two sharp styles, which embrace the lower part of the basioccipital. The parasphenoid is three-fourths the length of the head; it forms the only floor to the skull in the pituitary region (fig. 3, *py.*, *pa.s.*).

The bones that invest the skull above, and postero-laterally, will be described in the next stage, but partly also in the sections illustrating this. The splints of the first arch also will be described hereafter, but there is one which is figured on this Plate, namely, the preopercular. This bone (Plate 34, figs. 1, 2, *p.op.*) is a very narrow, but rather sharp splint, which is applied to, and takes the curves of, the lower edge of the suspensorium; it is the normal splint of the mandibular suspensorium, and is more like that of a Frog than that of an osseous Fish.

The length of the free mandible (Plate 34, fig. 4), as compared with that of the palato-quadrate, is as 20 to 19; it is, therefore, already a very long jaw. In its hind part it is nearly as broad as its pier, and then runs to its end as a somewhat stouter rod than the pterygo-palatine above it.

The condyle (*ar.c.*) is cylindroidal, concave as seen from the side, but somewhat convex across; there is an ectosteal "articulare" (*ar.*) in the broad part near the condyle. The angle is scarcely produced; but in front of the condyle, above, the cartilage grows into a pedunculated crescent of cartilage, the coronoid crest (*cr.c.*) The notch between this part and the lessening rod (*mk.*) is very deep; this leafy coronoid is convex outside and concave within. The long Meckelian rod (*mk.*) is gently arcuate and pointed at its fore end, where it nearly meets its fellow of the other side.

This skull is scarcely *amphistylic* even, much less *hyostylic*, for the pedicle of the mandibular pier is strong and well articulated, but the hyomandibular (*hm.*) is feeble, and the binding process or symplectic (*sq.*), feebler still.

The hyoid pier or hyomandibular (Plate 34, fig. 4, *hm.*), with its symplectic foregrowth (*sy.*), is about one-third the size of the palato-quadrate in front of it. The articular facet is a long, arched, convex condyle, with scarcely a perceptible neck; behind it is the knob for the opercular; below, this multilobate mass is sinuous, and scooped on its inner face to form the oblique condyloid facet for the interhyal. The front margin is concave, and the whole bulk suddenly lessens into a sigmoid style, bent first upwards, and then downwards, as it runs obliquely forwards to bind inside the hinder angle of the suspensorium, which is scooped to receive it. A small oval fenestra is seen in front of the middle of the hyomandibular; and around this, below the condyle, there is an ectosteal sheath. All but the front fourth of the symplectic also is ossified as a delicate shaft-bone.

The free or postero-inferior part of the hyoid arch is more evenly massive than its pier or antero-superior part. The conjugational piece, or inter-hyal (*i.hy.*), is pyriform;

it forms a loose joint inside the hyomandibular by its narrow upper end; and below, its inner face is scooped for the backwardly bent head of the cerato-hyal (*c.hy.*).

That segment is seven times the size of the inter-hyal joint; its head is bent back, its shoulder thickened, and has a short, separate ossification, the epi-hyal (*e.hy.*), and its shaft is rounded. The inferior condyle is hemispherical, and the main part of the thickest rod is ossified as the cerato-hyal (*c.hy.*).

The hypo-hyals (Plate 34, fig. 4, *h.hy.*) are sub-globular nodules, scooped above for the cerato-hyal, and ossified on their outside. They fit against the paired concavities of the basi-hyal (*b.hy.*)—a double, oblong, tongue-shaped, interglossal segment, as long, and twice as wide, as the cerato-hyal. This thickish plate is grooved above and below, is rounded and emarginate in front, and is composed of a spongy kind of cartilage, full of fibrous septa, which form a network in it.

There are four perfect, and one imperfect, branchial arches; they are less than half as solid as the hyoid (Plate 34, fig. 4, *br.*). In the mandibular arch, when the mouth is closed, the axes of the suspensorium and its free cartilage become coincident. In the hyoid arch they are *parallel*, not coincident; here, in the branchial arches, they are continuous, the upper being superimposed upon the lower element.

The relative size of these parts is greatly altered, and the subdivision does not exactly correspond with that of the mandibular and hyoid. The part answering to the suspensorium and hyomandibular is less than a fourth the size of that which corresponds to the mandible and cerato-hyal. Each "pier" is subdivided into two pieces—a pharyngo-branchial (*p.br.*) above, and an epi-branchial (*e.br.*) below. The upper piece is a little tongue of cartilage, turned inwards and forwards, and the lower has a short, bony shaft, and is a little rod turned directly downwards. These two segments *do not* correspond with the hyomandibular and symplectic; the upper piece has a double counterpart in the hyoid arch, namely, the hyomandibular and symplectic—one cartilage, with two bony centres in it.

Also, the counterpart of the cerato-hyal, the cerato-branchial (*c.br.*) articulates directly with its pier, the epibranchial; so that there is nothing in the branchial arches corresponding to the inter-hyal.

Instead of the hypo-branchials (*h.br.*) being short nodules, they are in the first two arches nearly as long as the cerato-branchials; are thicker than them below, but less ossified. The three joints between the four pieces seem to show no distinct joint-cavity, but are fibrous. Below, the rounded rods of the hypo-branchials fit into depression on the basal bar—basi-branchial (*b.br.*). This is, in front, a thickish, rounded rod of cartilage; it then thins out, and behind it is flat and emarginate. The first and second arch unite with the long, first basi-branchial segment; the third nearly reaches the short second piece, and the fourth is loosely attached to the side of the third piece, which is as long as the first. None of these pieces are ossified, and the first does not reach the basi-hyal, for the hypo-hyals are thrust between them.

The lessening third and fourth hypo-branchials (*h.br.*) are not ossified. The fifth

cerato-branchial (*c.br* ^{5}.) is less than those in front of it; it is not ossified, and there is no other segment in that arch.

The branchial arches are but little modified after this; they merely increase in size, and are always small as compared with the arches in front of them. A series of sectional views will complete the illustrations of this stage.

I have now to illustrate this stage by a series of sections made from a specimen $2\frac{1}{2}$ inches long.

Section 1.—This section (Plate 33, fig. 14) is taken from near the end of the snout in front of the nasal sacs. The intertrabecula (*i.tr.*) is seen to be oval, with the larger end below. The whole snout is elliptical, with a slight convexity above, and a slight concavity below, at the mid line. The premaxillaries (*px.*) are cut through, both in their body and their palatine process (*p.px.*); they are reticulations of thin laminæ, and both above and below enclose a mucous gland.

Section 2.—The nasal sacs are cut through here (Plate 33, fig. 15, *ol.*) and the bony laminæ are more complex; the intertrabecula (*i.tr.*) has the same shape as in the last, but the whole snout is rounder above and flatter below.

Section 3.—Behind the nasal sacs other bones come into view (Plate 33, fig. 16); here the evenly elliptical rostrum (*i.tr.*) has the laminæ of the ethmo-nasal (*et.n.*) surrounding it, and on the side a mucous gland is seen in the upper half of one of the maxillary chain (*mx'.*); here the lower face of the snout is becoming convex, with a median groove; above this, right and left, vomerine teeth (*v.t.*) are seen.

Section 4.—In this section (Plate 35, fig. 1) the lower jaw also is cut through; the snout is flatter here, has a ridged lip, right and left, with sub-marginal grooves. The intertrabecula (*i.tr.*), half-way between its fore end and the cornua (Plate 34, figs. 1, 2, *c.tr.*) is circular in section, and is flanked by the layers of the thickening ethmo-nasal (*et.n.*); outside, one of the maxillary chain (*mx'.*) is seen lying over the palatine (*pa'.*), with its large tooth, and under the rostrum the two vomers (*v.*), each with a small tooth, are cut through. Below, the mandibular rods (*mk.*) are cut through at their front part, and right and left we see the solidifying substance of the dentaries (*d.*); over the cartilage towards the mid line, a small, separated style is cut through—this is the splenial (*spl.*).

Section 5.—Another section in front of the angles of the mouth (Plate 35, fig. 2) brings the tongue into view. Here the rostrum (*i.tr.*) is deep, and twice the size it had in the last section; it is flattish above, and more convex below. Here the loose reticulation of the extremely thin bony laminæ would seem to defy interpretation; but it can be classified into groups, and these groups named. Under the flat top of the beak, on each side of the rostrum, several of these thin plates are seen to be connected together, overarching a mucous gland (*m.g.*) above, and the olfactory nerve (I.) lower down. Above these is a sub-marginal groove, right and left; outside this groove the beak is convex, and from the convex part there runs inwards a thin bony flake towards

the deep, palatal chink; this is the fore part of the frontal. Below this there is one of the maxillary chain (*mx'.*) cut through, protecting a gland; and inside this, on the lateral lobe of the beak, there is a wedge-shaped tract of fine diplöe, the lower part of which carries a large tooth; this tract is the palatine (*pa'.*) cut through. In the triangular median keel of the beak there are three thin plates cut through; two of them are superficial and the third is deeper, taking the form of the rostrum somewhat, but diverging externally, and having a short crus below—this is the parasphenoid (*pa.s.*). The paired laminæ running downwards and inwards, outside it, are the vomers (*v.*) in their widest part; they are overlapped by the inner end of the frontals, externally; which, at their outer end, overlap, obliquely, the sharp end of both the cornua trabeculæ and the pterygoid cartilages (*p.pg.*). Below, the thick lower jaws have in them the section of the MECKEL'S cartilage (*mk.*), large and almost circular. There is here the flat, double tongue, with its soft basi-hyal (*b.hy.*), also double. On each side of the tongue there is a deep sulcus. The splenial bone (*spl.*), over and within the cartilage, is here at its largest size, and the dentary (*d.*) takes up a large space by its reticulations; it encloses a mucous gland below.

Section 6.—This section (Plate 35, fig. 3) is through the angle of the mouth, and thus the upper and lower tracts are continuous; the lower or mandibular region is of great height, being cut through close in front of its huge coronoid region. Here the cornua trabeculæ (*c.tr.*) are at their thickest part, or middle (Plate 34, figs. 1, 2, *c.tr.*) and are continuous by a thin oblique tract, with the rostrum (*i.tr.*) which is at the thickest part in this and the next section. Here it is semi-elliptical above, and sub-carinate below, and the thin edges of the cornua ascend to their thick outer part; the olfactory nerves (I.) lie in the hollow between the bars. A little below the cornua the pterygo-palatines (*p.pg.*) are cut through; they are oval in section, their oblique position is parallel with that of the cornua, and their size is nearly as great. The mandibles (*mk.*) are oval in section, here, and twice as thick as the pterygo-palatines; the basi-hyal (*b.hy.*) is here at its widest part. The laminæ of the ethmo-nasals (*et.n.*), and of the frontals (*f.*) run close to each other, and below the pterygo-palatine there are two tracts of reticulated bone; these are the palatines (see fig. 2, *pa'.*) below, and the pterygoid (*pg.*) above. The splenial (*spl.*) is here at its widest part, and the dentary (*d.*) is composed of a large strip of bone, externally, and of a wide network, below.

Section 7.—The position of this section (Plate 35, fig. 4) is evident, for it is through the thickest part of the coronoid process of the mandible (Plate 34, fig. 4 *cr.c.*) where this remarkable crest is separated from the main rod by a large rounded notch. Here the cornua trabeculæ (*c.tr.*) are thinning out, behind, and the intertrabecula (*i.tr.*) is most solid, it is quite round above, and sub-angulate below. The pterygo-palatines (*p.pg.*) are oval and are further from the narrowed cornua (*c.tr.*)—they are twice as near to the coronoid cartilage (*cr.c.*) Below that crest,—which is placed obliquely across the face a little tilted upwards, and the section of which is oblong, but hooked inside—the main bar (*mk.*) is a large nearly vertical ellipse; here the basi-hyal (*b.hy.*) is very

wide. The ethmo-nasals (*et.n.*) are less, and the frontals (*f.*) are larger; the palatine is gone, and the pterygoid (*pg.*) is becoming a much thicker bone. Over the coronoid process (*cr.c.*) the supra-angular bone (*s.ag.*) is seen, the dentary (*d.*) is very extensive, and is helping the supra-angulare to cover the coronoid cartilage, and growing down the outside of and coming beneath the main rod (*mk.*) The coronoid bone (under *cr.c.*) now appears inside the mandible.

Section 8.—This slice (Plate 35, fig. 5) is a little in front of the hinge of the lower jaw, and behind the outspread wings of the trabeculæ; hence, the rostrum appears to be single, although it has the trabeculæ confluent with it in its lower half. About the middle there is a slight hollow; above, it is rounded, and at its base somewhat mammillate in section; this part has the parasphenoid (*pa.s.*) fitting to it, which is thus convex instead of carinate.

The pterygo-palatine (*p.pg.*) is oblique and oval; it is nearer the rostrum than the mandible; that part (*ar.c.*) is larger than the rostrum, and is irregularly spindle-shaped in section, with its upper half slightly incurved; in its inner face the "articular" centre (*ar.*) has appeared. The basi-hyal (*b.hy.*) is now wider, and thicker; flat above, and convex behind. The ethmo-nasal bone (*et.n.*) is narrower, and the frontal (*f.*) wider; the parasphenoid (*pa.s.*) has lost its keel, and become convex and alate. The pterygoid (*pg.*) has now more diplöe above, is growing far down as a thin lamina inside the angle of the mouth; the dentary (*d.*) lies on both sides of the lower half of the cartilage; above, the supra-angulare (*s.ag.*) lies over it, and below, the angulare (*ag.*) flanks it.

Section 9.—A little further back (Plate 35, fig. 6) we get a similar section to the last, but the pterygoid (below *p.pg.*) is still more complex, above, and the articular cavity of the hinge of the lower jaw (*q.c.*, *ar.c.*) is laid open, and has a piece of the quadrate in its hinder face.

Section 10.—This is through the fore part of the eye-ball (Plate 35, fig. 7, *e.*); and here, the upper part of the chondrocranial mass is thicker; for it is in the ethmoidal region, and the olfactory nerves (I.) now run through tunnels in the closed-in skull. At this part the suspensorium is cut through in the quadrate region (*q.c.*); it appears as a sigmoid tract; thin above, thicker and rounded below, and with its upper, slightly out-turned, edge not far from the cranial axis. Below, the basi-hyal (*b.hy.*) is becoming more solid. Here each frontal is mainly a flat lamina, becoming complex externally; some of the complex outer part, however, belongs to a circumorbital. Inside the suspensorium the pterygoid (*pg.*) is a sigmoid tract of diplöe, and below the cartilage a small, triradiate tract of bone is cut through; this is the preopercular (*p.op.*).

Section 11.—Here (Plate 35, fig. 8) the cranium is cut through where the olfactory lobes (C^{1b}.) lie; it is therefore behind the proper septal portion of the intertrabecula, and shows the beginning of the tegmen cranii (*t.cr.*). The other parts are similar to those exposed in the last section, but, here, the quadrate bone (*q.c.*) is seen in the lower part of the suspensorium, as an enclosing ectosteal plate.

Section 12.—A little further back (Plate 35, fig. 9) the section is through the

hemispheres (C^{1a}.), and is behind the quadrate bone; the other parts are similar to those in the last two sections.

Section 13.—Here (Plate 35, fig. 10) the hemispheres (C^{1a}.) are wider, and with them the cranial cavity, whose walls are thinner, and laterally are partly ossified; these bones right and left, are the lateral ethmoids (*l.eth.*); they were not seen in the dissection of the lesser specimen of this stage; (2 inches long, Plate 34; the one sectioned was $2\frac{1}{2}$ inches); but these bones are figured in the dissection of the next stage (Plate 38, figs. 2, 3).

Looking at the base of the cranial axis in this and the last three or four sections, we see that the parasphenoid (*pa.s.*) fits to a cartilaginous mass having a *trilobate outline* below; this arises from the fact that it was formed by the coalescence of three cartilages, viz.: the trabeculæ and the intertrabecula.

Section 14.—The hemispheres in this section (Plate 35, fig. 11, C^{1a}.) are rapidly widening, and the cranial walls are now deficient, the sides being membranous—the orbito-sphenoidal fenestra—in the lower half. The tegmen cranii (*t.cr.*) runs down the sides half way, and is grooved above; the lower edge of the cartilage just touches the optic nerve (II.). Here the base of the skull has lost its height; it is concave above, and scooped below. Here is the hinder end of the intertrabecula, and the trabeculæ (*tr.*) are each of them crested below. The suspensorium is very flat here, especially towards the top; it thickens out again above, and is surmounted there by a small extraneous bony plate—the mesopterygoid (*ms.pg.*, see also Plate 34, figs. 1, 2); here the pterygoid (*pg.*) has become a thin plate. The essentially double nature of the basi-hyal (*b.hy.*) is clearly seen in this section.

Section 15.—The hinder part of the hemispheres (Plate 35, fig. 12, C^{1a}.) are now cut through, and the tegmen cranii (*t.cr.*) is now a thin, sinuous awning thrown over the brain-cavity; it is hollow above, and convex at the sides. The frontals (*f.*) are becoming thin, and the hinder superorbitals (*s.ob.*) are thick and large. The trabeculæ (*tr.*) only are seen in this section, which is through the fore part of the long pituitary space (see Plate 34, fig. 3, *py.*); they are oval in section, and a space equal to their width is filled up between them by the parasphenoid (*pa.s.*).

The suspensorium (*q.c.*) has thickened again, and still the same bones are applied to it, namely: the mesopterygoid, pterygoid, and preopercular (*ms.pg.*, *pg.p.*, *p.op.*). Below, the section was made behind the basi-hyal, and through the first basi- and hypo-branchials (*b.br.*, *h.br'.*); outside, we see the cerato-hyal (*c.hy.*), with its bony sheath, cut through.

Section 16.—In this section (Plate 36, fig. 1) the skull is cut through close in front of the basi-pterygoids (Plate 34, figs. 1–3, *b.pg.*); in this specimen there must have been some little projection backwards from the front tegmen (*t.cr.*), not seen in the one dissected; this would have made the fontanelle heart-shaped, instead of circular.*

* This projection from the front "tegmen" was seen in the last stage (Plate 32, fig. 4, *t.cr.*), where the fontanelle has a similar shape to that of a young Salmon of the 2nd week. ("Salmon's Skull," Plate 4, figs. 1, 2.)

Here the cavity of the skull is at its widest part; further back the width of the head is due to the addition of the auditory capsules, but the hind brain (C^3.) is only half as wide as the mid brain (C^2.). Here the razor passed from the front of the fontanelle, above, to the middle of the fontanelle, below, just where the trabeculæ pass into the investing mass (*iv.*), and behind the optic foramina (see Plate 35, figs. 11, 12); the section is therefore somewhat oblique, backwards and downwards. The slight projection from the front tegmen (*t.cr.*) is wide apart from the alisphenoidal region, or lateral band of cartilage (*al.s.*), which is thickish, convexo-concave, and occupies more than half of the side wall.

Below, under the thalamencephalon, the parasphenoid (*pa.s.*) is thick and narrow, and is strongly wedged in between the narrowest part of the basal bars (see also Plate 34, fig. 3, *tr.*, *iv.*, *pa.s.*), which are oval in section, and slightly tilted outside. Between them and the alisphenoidal tract (*al.s.*), part of the trigeminal nerve (V.) is seen. Above, the parietals (*p.*) are cut through, and also a lateral bone—the squamosal (*sq.*). Here the suspensorium (*q.*) is, in section, like a drumstick, but feeble below and out-turned, for it thins down towards its lower thickening, and there bends outwards over the small, round symplectic (*sy.*). Above, it is round, very solid, and sheathed at the very top with a bony tract; this is the "metapterygoid" (*mt.pg.*) which is cut through.

Below, the preopercular (*p.op.*) is seen as a small tract of diplöe, enclosing a mucous gland; inside it, the cerato-hyal, with its ectostosis (*c.hy.*), is severed, and further inwards the basi-branchial and the first and second hypo-branchials (*b.br.*, *h.br*^{1}., *b.br*^{2}.).

Section 17.—We have now a section (Plate 36, fig. 2) close in front of the pituitary body, but missing it; it is through the infundibulum (*inf.*) below, and the mid brain (C^2.) above, and catches the terminal point of the small tegminal projection; this thin slice was the next to the last, which is not always the case in those which are figured.

Here the basipterygoid processes (for *q.* read *b.pg.*) are seen as thick wings growing from the front part of the investing mass;* they are partly ossified by the lower edge of the alisphenoidal centre; they are thin at their root, thick outside, and they dip a little; above them, the 5th nerve (V.) is cut through. Here the parasphenoid (*pa.s.*) sends out its first pair of angular projections (Plate 34, fig. 2), so that it forms a bony floor to the skull. Above, the parietals and squamosals (*p.*, *sq.*) are seen in section, and also one of the numerous post-orbital scales. The symplectic (*sy.*) is cut off where it has a bony sheath, as it passes forwards to the suspensorium. The cerato-hyal (*c.hy.*) is trilobate here in section; outside, it is the interopercular (*i.op.*); the branchial sections are of the same bars as in the last.

Section 18.—This (Plate 36, fig. 3) is through the fore part of the hind tegmen (*t.cr.*), and where the mid brain passes into the hind brain (C^3.). Here the head is slightly concave above; the roof-cartilage is rather thin, and forms part of a nearly complete cincture, for it is confluent here with the fore part of the auditory capsule (*au.*), which in

* Two errors escaped me in the lettering of this figure,—for *q.* read *b.pg.*, and for *mt.pg.* read *iv.*

turn passes into the investing mass (*iv.*) below. There the cartilage is a thick wedge, right and left, and the space between the two wedges is filled in by the parasphenoid (*pa.s.*); in front of the apex of the notochord. Where these basal plates pass into the capsules there the facial nerve (VII.) is severed, and further outwards the capsule has a groove under it in which the fore part of the head of the hyomandibular (*hm.*) is seen; it is partly ossified above and also below as the symplectic. A neat lip, the rudimentary "tegmen tympani," is seen outside the rod, and above it the ampulla of the anterior canal (*a.s.c.*), whose arch also is severed higher up. The bony tracts below are parts of the large, infolded, angular interopercular (*i.op.*, see also Plate 37, fig. 4, *i.op.*).

The second, third, and fourth hypo-branchials and the middle of the basi-branchial (*h.br*$^{2\text{-}4}$., *b.br.*) are severed, and the gills are seen depending over the fore part of the heart (*h.*).

Section 19.—The roof is now in the superoccipital region (Plate 36, fig. 4, *t.cr.*); it is twice as thick and only two-thirds the width at this part, as compared with the last. Here the hind brain (C^{3}.) has only membranous sheets interposed between it and the auditory labyrinth, which is deficient in its cartilaginous wall in this, the region of the "meatus internus," where the auditory nerves (VIII.) enter. The section of the hyomandibular (*hm.*) is here behind the symplectic; above its head the horizontal canal (*h.s.c.*) is cut through and the end of the arch of the anterior canal (*a.s.c.*) is seen to come close to the great inner "fenestra" of the capsule. Here, as in Sharks and Skates, the basal plate (*iv.*) projects beyond the capsules, and in the angular space the 7th nerve (VII.) is cut through.

Below, this section is still in front of the notochord, but the parachordals (*iv.*) bend down very near to each other; they are supported by the parasphenoid (*pa.s.*). Here the branchial arches (*h.br.*, *b.br.*) are cut through near their hinder part; below, their gills (*g.p.*) are seen hanging over the heart (*h.*), and the interopercular is seen outside the hyomandibular (*hm.*).

Section 20.—In this slice (Plate 36, fig. 5) the apex of the notochord (*nc.*) is cut through, and here the auditory capsules have recovered their inner wall; the end of the horizontal (*h.s.c.*) and the part leading to the common sinus of the anterior (*a.s.c.*) and posterior canals are cut across. The vestibule (*vb.*) is lessening here, where the back of the "sacculus" is shown. The hyomandibular is severed behind its head, and outside it the interopercular and subopercular are shown in section in the fold (*op.*). Here a ganglionic mass belonging to the 9th and 10th nerves (X.) is brought into view; and above, the parietals and one of the temporal series (*s.t.*) are severed.

Section 21.—The back of the auditory capsule, with the ampulla and hind part of the posterior canal (Plate 36, fig. 6, *p.s.c.*), are now severed; here the double passage for the 9th and 10th nerves and the nerves themselves (IX., X.) are seen; the bony laminæ are severed that are finding their way into the back of the auditory capsule; in the cavity of the ampulla, and from the foramen over the top of the oblique lower

part of the occipital arch, there are parts of the spreading exoccipitals (*e.o.*). The opisthotic and epiotic are formed over the posterior canal *later* (see Plate 38).

The two halves of the investing mass, below, form a rest for the oblique plates of the upper part or arch, and are only slightly tilted upwards outside; they are thick inside and flattish on the outside, and have the notochord (*nc.*) between them; this rod is, here, ensheathed in bone, and this thick bony sheath has sent a wing, right and left, over the basal part of the moieties of the investing mass, which are curling over their external edge, as far as to the edges of the underlying parasphenoid (*pa.s.*); this ectosteal growth is the basioccipital (*b.o.*). The top of two of the branchial arches (*p.br.*), the parietal (at its end), and a supra-temporal bone are also seen. In this section the occipital arch is seen to be two-winged, right and left; in the last stage (Plate 33, figs. 12, 13, *iv.*) the section, here, was like an hour-glass.

Section 22.—The roof is now (Plate 36, fig. 7, *s.o.*) very thick, and here the vagus nerve only (X.) is seen with its ganglion; the back wall of the auditory capsules nearly meet above; the basal plate (*iv.*), between the halves of which the osseous sheath of the notochord (*nc.*) is seen, with its right and left basioccipital wings (*b.o.*), is surmounted by the side plates of the arch (*e.o.*). Behind the horizontal canal the combined occipital arch and auditory capsules form large thick shoulders of cartilage; whilst, above, the arch has three roundish crests (*s.o.*). Here the basal plate (*iv.*) is thicker, and as in the last, the parasphenoid is corrugated; the wings of the basi-occipital bone (*b.o.*) do not yet invest the lower face of the cartilage; the opercular (*op.*), and a post-temporal scute, are seen in section, as also some parts of the hinder branchial arches (*br.*), with their pectinate gills and grooving vessels. Here the peculiar *four-fold* nature of the occipital arch is well seen, the oblique sides resting on a projecting threshold, through which the notochord, with its bony sheath, runs.

Section 23.—The last of the sections (Plate 36, figs. 8, 9) figured is through the thinner hind edge of the occipital ring, which is lozenge-shaped, and somewhat winged, right and left, for the side-walls have the same obliquity as the halves of the archway above; here the threshold is not so wide as in the last section; it is narrowing towards the end of the projecting basioccipital (see Plate 34, figs. 1–3, *b.o.*).

The exoccipital ectosteal plate (*e.o.*) is seen inside the converging arch, the right and left plates nearly meet above, and there is no key-stone piece or supraoccipital bone in the rounded median part. Here the notochord (*nc.*) lies impacted between the basal plates and their ascending arch; it is the core of a strong basioccipital bone (*b.o.*), which strongly encloses it, the soft tissue spreading in radiating lobes in the thickening bone-substance. Laterally, the bone has spread so as to enclose the halves of the investing mass, and runs beyond these parts; it grows as a right and left sharp plate. Here the wide corrugated parasphenoid (*pa.s.*) is in two parts, for it is forked behind (see also Plate 34, fig. 2, *pa.s.*).

Sixth Stage.—Young Lepidosteus, 4 *inches* 5 *lines long.*

In this stage the dermal scutes are so well developed that they can be named and classified ; I shall describe them first, and the endocranium afterwards.

Notwithstanding the size of this specimen it had still the remains of the embryonic suctorial disk at the end of the snout (Plate 37, figs. 1–3), forming a pad on the end of the premaxillaries (*px.*), and lying in a horizontal plane. The lower jaw just reaches this part, the disk, itself, overlapping it.

The rostral region of the head is twice as long as the cranial ; the opercular bones (*op.*, *s.op.*), pass behind the projecting basioccipital (*b.o.*)

The mandibles are two-thirds the length of the head, and as in embryo Frogs, are articulated to the quadrate *in front of the eye-ball* (*e.*) ; in old Frogs the condyle of the quadrate may reach as far backwards as the opercular folds do in this Fish.

The bony scutes of the hinder part of the head and face do not differ much from those covering the body, except in size ; but in the rostral region, both above and below, but especially below, many of the bony plates are styles of great length and tenuity ; this is a specialization quite like that which is seen in the skulls of longirostral Birds, and in some extinct Sauropsida, *e.g.*, the *Ichthyosaurus.*

Most of the bones of the roof are not difficult to decipher, for the eye detects quickly the parietals, frontals, and squamosals (Plate 37, fig. 1, *p.*, *f.*, *sq.*) ; but nearly the whole extent of the rostrum has to be traversed before we reach the true nasals. These bones (*n.*) are small crescentic scutes that cover the small, distal olfactory capsules (*ol.*) But along the top of the rostrum, from the ethmoidal region, where the frontals diverge nearly to the nasal roofs, two long, narrow styles of bone are seen ; these I propose to call " ethmo-nasals " (*et.n.*) ; they are manifestly separate centres that correspond to the elongated hinder part of the nasals of a Bird.

The olfactory sac, in both Ganoids and Teleosteans, is devoid of a proper paraneural roof, and the bone covering it is merely one of the many " slime-bones" seen in the skulls of these Fishes ; still, that scute which directly covers the olfactory organ has the first claim to be called the nasal. The frontals (*f.*) in their foremost third are divarcated and styloid, embracing the hind end of the ethmo-nasals (*et.n.*) ; they are wide where they meet over the antorbital region, become pinched up to their hinder fourth, and then widen most where they are overlapped by the parietals. These latter bones (fig. 2, *p.*) are large and oblong, covering the skull well from the middle of the eye-balls to the back of the ear capsule ; they are flanked and overlapped by the temporal series.

The principal temporal bone is the squamosal (*sq.*); it is a long and irregular triangle, with its sharp end foremost ; its broad end is overlapped by the second large temporal (*s.t.*), which covers the hinder part of the parietal as a rounded scale. Under it there is a lesser pair, and under these upper, larger bones, there is a considerable patch of small scutes margined by the circumorbital series in front, and the angulated interopercular

(*i.op.*), behind. The circumorbital series is a very perfect ring of small scutes round the eye-socket; of these the antero-superior scales are the largest. A short chain of three or four small scutes runs forwards from the *superorbital* part of the ring; these may be called *preorbitals* (*p.ob.*); they are tilted up and form a sort of "eave" to the large convex coronoid part of the mandible. There, indeed, in front of the eye-balls, the skull is pinched inwards, and set, as in a vice, between the high hinder part of the lower jaw, whose steep, almost vertical, hind margin chafes, so to speak, right and left, against each circumorbital ring (Plate 37, fig. 1).

Below the tilted preorbitals there is another short, feeble chain of three or four scutes; the last but one of these (*m.x''.*) is as long as the others together, and has all the relations of the free part of the edentulous "os mystacum," or maxillary of typical Teleosteans; the little scute behind it (*j.*) shows the same relations as the small malar (jugal) of many Teleostei.

Outside of and protecting the sub-marginal row of mucous glands, there is a long chain of bones (see Plate 32, fig. 5, *m.c.g.*, and Plate 37, figs. 1, 2, *m.x'.*); this series of scutes is the continuation of the *mystaceum* series (*m.x''.*, *j.*) but thrice their width; this may be called the *maxillary chain.* This is composed of about fourteen or fifteen very similar scutes; they are oblong, their width being about half their length. In front of these the small premaxillaries (*px.*) are seen to be distinct, right and left. Each moiety (or centre) is pointed in front, has a small palatine plate and a dentary edge with sharp teeth; these rows of teeth (fig. 3, *px.*) meet in front at an acute angle.*

Behind the palatine plate of the premaxillaries, right and left, there is a long bone in close contact with its fellow of the opposite side, and so slender that the two together are not so wide as a single ethmo-nasal (fig. 2, *et.n.*); these "needles" are the vomers (fig. 3, *v.*); they become covered with a very fine rasp of teeth, and are nearly half the length of the entire skull.

Bounding these, along the palatal face of the rostrum, there is a pair of bones one seventh longer than the vomers, and twice as wide; these are the "parosteal palatines" (*pa'.*). These bones become invested with a rasp of teeth a degree coarser than that on the vomers.

In the long valley between these palatine splints and the maxillary chain there is a row of *large* sharp teeth, and on the edge of the chain an outermost row of *small* sharp teeth. A very long carinate, trough-like bone runs over the hind part of the two vomers for a considerable distance, and then extends to the end of the skull; on escaping from them it appears also rough, with a fine rasp of teeth. Further back these teeth cease, but the bone is carinate up to the basi-pterygoid (*b.pg.*); this is the parasphenoid (Plate 37, fig. 3, *pa.s.*) This bone is wider in the ethmoidal than

* In an old specimen I find a flat sub-arcuate scute binding across in front of the distant premaxillaries; this latter bone might be thought to be an edentulous azygous premaxillary and the two next behind it, not premaxillaries, but the foremost of the maxillary chain; I incline to call it a prenasal.

in the post-orbital region, but it then widens to thrice its breadth even in the ethmoidal region. It flanks the basipterygoids (*b.pg.*) with a pair of small wings, is spread out under the auditory capsules (*au.*), and applies itself as a forked splint to the under face of the basioccipital (*b.o.*). Behind, for three-fifths of their length, the palatine splints (*pa'.*) are bound on their inner edge by a larger, but similar bone; this is the pterygoid (fig. 3, *pg.*); both these bones are seen in their relation to the suspensorium in other figures (Plate 37, fig. 4, and Plate 38, fig. 5, *pa'.*, *pg.*). The pterygoids acquire a fine bony rasp when they lie close to the palatal surface. Each bone is a long style in front, and then widens gradually so as to become a broad spatula in the orbital region.

The styloid palato-pterygoid cartilage is applied to its outer face above, but the bone passes backwards, and invests three-fourths of the inner face of the broad suspensorium (see Plate 38, *pg.*), ending behind, with a thin, rounded margin.

When these parts are removed from the rest of the skull (Plate 37, fig. 4, and Plate 38, fig. 5) their parosteal relation to the prognathous suspensorium is clearly seen.

Over the edge of the suspensorium, in its broadest part, there is a *third* parostosis; this is the mesopterygoid (Plate 37, fig. 4, and Plate 38, fig. 5, *ms.pg.*). It is a thin, falcate bone above, one-sixth the length, and one-sixth the width, of the pterygoid.

A *fourth* splint is applied to the suspensorium, and this, like the last, is extremely small as compared with what is seen in the Teleostei; this is the preoperculum (*p.op.*); this bone is falcate, narrow, gently curved downwards, pointed behind, where it lies on the interopercular, and roughly notched in front, where it binds on the outside of the quadrate bone (*q.*); it is only one-third the length and one-third the width of the succeeding bone—the interopercular (*i.op.*); whereas in the Teleostei it is much the larger bone, as a rule.

The free part of the lower jaw, or mandible, is of great length, and the dentary bone covers it from end to end (Plate 37, fig. 4, *d.*); on the inside (Plate 38, fig. 5, *d.*) it is only seen at the edges of the jaw. Under its upper edge, on the inside, a much smaller bone, three-fourths its length, binds on the upper edge of the cartilaginous axis (*mk.*); this is the splenial (*spl.*).

Behind the splenial, on the inner side (Plate 38, fig. 5 *cr.*) the coronoid is seen as a pedate tract of bone with its heel behind; it binds on the inside of the fore part of the large cartilaginous coronoid (*cr.c.*). Under the short angular process of the articular cartilage there is a small angulare (*ag.*), and outside the large, ear-shaped coronoid cartilage, on its convex face, there is a considerable scale of an oval shape, and placed obliquely forwards and upwards; this is the supra-angulare (Plate 37, fig. 4, *s.ag.*).

The specialised "scutes" just described belong to the mandibular arch; those next to be noticed belong to the hyoid. On the knob of the hyomandibular a large oval scute is articulated by its capped fore end: this is the operculare (Plate 37, fig. 1, *op.*); below this a similar bone is seen, but of an uncinate or semi-crescentic form, with its sharp end behind, and its upper edge inside the operculare; this is the sub-operculare (*s.op.*).

Binding on the fore edge of the two last, we see an angulated sub-crescentic bone, with its concave edge above, its angulated margin below, and its front point binding under the hind point of the preoperculare. This is the interoperculare (Plate 37, fig. 4, and Plate 38, fig. 5, *i.op.*). These three bones are the hyomandibular splints; those now to be described belong to the cerato-hyal; these are the branchiostegals: they are beneath and within the great operculum (Plate 37, fig. 1, *br.s.*), and are attached in front to the cerato-hyal. Generally *seven* in number in the Teleostei, there are only *three* here, as in the Carp. These bones are narrow and falcate, with their concave margin above; the uppermost is the largest; the lower is the least.

The remainder of the bones which I have to treat of are *intrinsic* centres, or "ectostoses;" they will come under notice, now, in a description of the endocranium, most of which, however, is cartilaginous.

The endocranium at this stage differs but little from that of the adult, in which, although the bony centres become dense and relatively larger, are yet not altered, either in their number or relations, to any appreciable degree.

In this skull, the "prenasal rostrum," or intertrabecula, is as much developed as in the most specialised of the Selachians—namely, the "Pristidæ," or *Saw-fishes*—much more than in the ordinary Skate ("Raiidæ"). Here the length of this precranial region is, as compared with the cranial cavity, as 14 to 5, or nearly three times as long. In an old specimen the cranial cavity is only 2 inches long, and the whole skull $12\frac{1}{2}$ inches, or 2 to $10\frac{1}{2}$; the brain has, relatively, retreated. Measured from the quadrate condyle, in this young stage, we get the same proportion as the measurement of the precranial to the cranial; in the old the prequadrate region is 9 inches long, and the post-quadrate $3\frac{1}{2}$ inches.

This remarkable pyriform, long-stalked skull owes its greatest expansion to the superaddition behind of the large ovoidal auditory capsules, and next to them to the greater size, in the young, of the mid brain; it soon narrows in over the small hemispheres. As in the last stage, the roof of the mid brain is membranous—this is the large circular fontanelle (Plate 38, fig. 1, *fo.*), the margins of which are very moderate bands of cartilage—the postorbital part of the superorbital bands (see Plate 30, fig. 8, *so.b.*).

Below (Plate 38, fig. 3, *py.*, *pa.s.*) there is a rather large and lanceolate pituitary fontanelle; and inside the orbits (Plate 38, fig. 2, *o.s.f.*) there are the long "orbito-sphenoidal fenestræ." The upper fontanelle (*fo.*) takes up about a third of the roof, but it is not so long as either the fore or the hind part of the tegmen cranii (*t.cr.*). Thus although this is rather a well-developed chondrocranium it has four large membranous deficiencies in it.

The basioccipital (Plate 38, figs. 1–3, *bo.*) might be taken for the centrum of the first vertebra—it projects so far behind the exoccipitals (*e.o.*). The bony matter, which did occupy much of the sheath of the cranial notochord, is now mainly confined to its hind part, and forms a four-sided mass; this mass does not run forwards into the rest of the notochord—at least on its upper surface (Plate 9, fig. 3, *nc.*).

This rugous bone is broadest behind, where it is scooped for the first vertebra; above, it is flattened; its fore end is emarginate, and its two oblique antero-lateral faces are joined by suture to the exoccipitals (*e.o.*)

These bones are small lunate tracts behind the passages for the 9th and 10th nerves (IX., X.); the rest of the occipital arch is devoid of bone, for the superoccipital is absent, as in the Amphibia; that region projects, as an obtuse angle of cartilage, over the foramen magnum.

The auditory capsules project well into the basal plate (*iv.*); their canals (*a.s.c.*, *h.s.c.*, *p.s.c.*) are large, and easily seen through the transparent cartilage; both above and below they send their diverticula inwards towards the mid line, so as to make the roof and floor of the skull into the shape of an hour-glass. The upper part spreads outwards over the horizontal canal, covering the facet for the hyomandibular (*hm.c.*); further inwards, below, the swelling "sacculus" on each side makes a notable bulging, which is partly floored by the parasphenoid (*pa.s.*). Postero-laterally, the capsules are but slightly angulated; but in front they grow outwards and forwards into an ear-shaped projection, which is separated by a round notch from the root of the supra-orbital band (*s.ob.c.*). That process is the "sphenotic" outgrowth of the chondrocranium in front of the capsule; it is becoming bony (Plate 38, figs. 1, 2, *sp.o.*); also below, in front of the capsule, and surrounding the chinks and openings for the 5th and 7th nerves (V., VII.), the prootic centre (*pr.o.*) is spreading into the cartilage; in front it runs into the back of the corresponding basipterygoid (Plate 38, fig. 3, *b.pg.*); and behind it has reached the concavity for the sacculus (*vb.*)

Also above (figs. 1 and 4), an irregular bony tract is seen imperfectly divided into two patches, which lie over the ampulla of the posterior and the end of the horizontal canal (*p.s.c.*, *h.s.c.*). The upper part is the rudiment of the epiotic (*ep.*), the lower portion of the opisthotic (*op.*).

In front of the basipterygoid (figs. 2, 3, *b.pg.*), and rising upwards from it into the limited tract of cartilaginous wall between the orbito-sphenoidal fenestra and the ear-capsule, there is a bony tract, smaller than the prootic and next in front of it; this is the alisphenoid (*al.s.*).

Along the skull base, in front of the projecting basioccipital, there is no intrinsic bony centre, and laterally, the whole orbito-sphenoidal region is membranous.

But where the skull is closing in, in front, the rapidly narrowing cranium has a short tract of cartilage in its sides; this is the lateral ethmoidal region; the free border of this cartilage in front of the fenestra is ossified as a crescentic patch (Plate 38, figs. 2, 3, *o.s.f.*, *l.eth.*); this answers to the so-called prefrontal of the Teleostei, but it does not grow out into ethmoidal wings, as in those types.

A very important change has taken place inside the basis cranii, for now there is a very definite "posterior clinoid" *bridge*, not *wall*, of cartilage (Plate 38, fig. 3, *p.cl.*); it is small, very narrow in the middle, and runs straight across, joining the roots of the trabeculæ (*tr.*) together, but lying only at a small height above them.

This is a very feeble rudiment of the thick and high wall, which is developed in this part in most of the "Amniota," where it runs up in the deep fissure under the mid brain. However, even here it divides the basi-cranial fontanelle into two parts, a large anterior (*py.*) and a small posterior space (*p.b.c.f.*).

Thus it is evident that in this, as in other kinds of Ichthyopsida, the basis-cranii is much less affected by the mesocephalic flexure than it is in the Sauropsida and Mammalia.

The main pituitary space (Plate 38, fig. 3, *py.*) is lessened by the ingrowth of the trabeculæ (*tr.*); but in front, it is filled in by the hind part of the long intertrabecula. The trabeculæ are bowed out right and left, between the 5th and 2nd nerves (V., II.); the 1st nerve (I.) escapes from the front of the enclosed end of the cranium, and runs all the distance to the nasal sacs close to the sides of the intertrabecula (*i.tr.*)

The paired trabeculæ (*tr.*) do not end where the skull has closed in; in front of the narrowed tegmen cranii (Plate 38, figs. 1, 2, *t.cr.*) the intertrabecula is seen to be narrow above, and to have narrow wings running along its sides.

These wings soon dilate, so as to give the rostral part of the skull an oval widening along the front *two-fifths* of its *hinder fifth*. These parts are the cornua trabeculæ, and although they are so short now, they were (Plate 30), once, the main part of the skull in front, and for some time came little short of the end of the snout. Now, they are like the right and left sides of a lanceolate leaf, with a huge mid-rib; only their terminal point is free, and the 1st nerve runs in a groove between them and the long rostrum.

The rostrum (*i.tr.*) is very uniform up to near the front end; it then becomes slightly alate before ending in a blunt and somewhat decurved point (*p.n.*); its section is nearly oval, the thicker end below.

The suspensorium (Plate 37, fig. 4, and Plate 38, fig. 5) retains the form it had in the last stage (Plate 34), but it is twice as large, and its bony centres are now perfect. The upper bone is the metapterygoid (*mt.pg.*), it occupies the neck of the suspensorium, leaving cartilage, however, on the concave articular facet—for the basipterygoid—and also on the short round "trochanter," below the joint; this spur is the arrested otic process (*ot.p.*).*

The quadrate (*q.*) is a bony quadrant running, at its angle, close to the articular condyle (*q.c.*); this latter is an elegant convexo-concave trochlea, with its largest convexity on the outside. The main part of the body of the suspensorium is unossified; it is a large oblong tract, with its postero-inferior angle rounded off; it is rather hollow outside and convex within, where it is invested by the pterygoid bone (*pg.*).

The pterygo-palatine rod (*p.pg.*) is unaltered since the last stage; it never ossifies, and reaches as far forwards as the cornua trabeculæ (*c.tr.*).

The articulo-Meckelian rod (*mk.*, *ar.*) has increased in size (both actually and

* In Plate 38, fig. 5, below, for *pa.* read *pd.*

relatively); its intrinsic centre also, the articulare, has become two separate points of bone (Plate 38, fig. 5, *ar.*). The rest of this long, subarcuate, terete rod (*mk.*), runs along the grooved inner face of the dentary (*d.*) nearly to its distal end. The coronoid crest (*cr.c.*) is a very large "ear" of cartilage; it is convex outside and hollow within; its fore part is a free lobe.

The hyomandibular (Plate 37, fig. 4, and Plate 38, fig. 5, *hm.*) is a remarkable bar, about half the size of its "serial homologue"—the suspensorium. Its arched, extended head is a convexo-concave condyle for articulation under the horizontal canal; behind this there is a cartilaginous knob for the opercular bone. The bony shaft is short, pinched in the middle, and has an oval fenestra near its front third. Below the shaft it swells out into a solid bilobate mass, the lesser lobe being behind. In front of the fore lobe, on the inside, there is a concavity for the inter-hyal (*i.hy.*). The bar from that point becomes the small sigmoid symplectic (*sy.*); it is bent downwards suddenly, and then runs straight forwards to lie along the inside of the hinder third of the lower edge of the suspensorium.

Its bony shaft occupies its hinder two-thirds; where it becomes straight, there it has a small bony elbow; its fore end is a blunt point (Plate 38, fig. 5, *sy.*).

The inter-hyal (*i.hy.*) is a small pyriform cartilage, its narrow end fits into the concavity in the hyomandibular, and its broad end has a cup on its inner side for the head of the cerato-hyal (*c.hy.*).

The latter segment has a "trochanter" behind its small rounded head; its shoulder is ossified as a separate epi-hyal (*e.hy.*); the main shaft (*c.hy.*) has its own centre; it is narrower in the middle, and is only separated from the stylo-hyal by a tract of cartilage.

The rounded lower end of the cerato-hyal fits into the oblique shallow cup of the sub-globular hypo-hyal (*h.hy.*); this short segment is ossified on its outer face; at present, at any rate it has no second centre, as in the Teleostei; but in these, as in *Acipenser*, it is completely segmented off from the cerato-hyal.

The basal piece (*b.hy.*) is a large "inter-glossal" plate as long as all these three segments above it; it is oblong, rather pinched in the middle, emarginate in front, thickish, and somewhat fibro-cartilaginous, having cross-bands and reticulating, connective fibres, wrought into it on its upper surface, and its hyaline cartilage somewhat softer than in the other parts.

The basal piece of the branchial system, and part of the first part of hypo-branchials (*b.br.*, *h.br'.*) are figured. For the rest, I must refer to the figures and descriptions of the last stage; these parts have not altered in any important degree —except in size.

Comparison with other types, and Summary.

As soon as the primordial cranium becomes sufficiently differentiated—as hyaline cartilage—to be distinguished from the rest of the cephalic mesoblast, we find a

peculiarly simple foundation for all the aftergrowths. In Stage 1, in embryos $10\frac{1}{2}$ m.m. long, nearly all the parts of the chondrocranium—including in this term the visceral arches—are present; the hinder arches become broken up, afterwards, but the two first, and largest, the mandible and hyoid, are already as much segmented as they will be in the adult.

The skull-floor, only, is developed, as yet, and the rostral part, in front, is not chondrified, but its outlines can be traced, and the roof and walls of the skull are merely developments from the basal bands.

Those bands in this type lend no support to the theory of the visceral (or ventral) nature of the *pro*-chordal tracts or *trabeculæ;* they are, manifestly, mere continuations of the undivided *para*-chordal cartilages, which expand and contract in relation to the parts around and over them. They diverge from the front third of the notochord, as though their relation to it was not intimate, and show—for a long while at least—no tendency to grow up, with that axis, into the hollow of the mid brain.

I see nothing in this lyriform basal skeleton of the skull but an undivided *basi-neural* structure comparable to, and a *primary cephalic variation* of, the tracts that form the paired rudiments of the *neuro-central* cartilages of the spine. The cessation at the end of the notochord (mesially), and close behind the oral opening, laterally, of the hypo-blastic layer, causes all the pre-oral and pre-pituitary parts to be, in a sense, imperfect; they are developed as porches and outworks to the full and complete structure further back, but this does not destroy their homology, nor break their continuity with the parts formed from their own embryonic layer, of which they are the direct ongrowths.

Yet all parts growing out,—forwards, upwards, or downwards,—in front of the perfect axis, which ends close in front of the infundibulum, must be very cautiously named as "serial homologues" of the perfect base and its upper and lower arched growths; they are probably mere *outgrowths;* at most they are only *rudiments.*

The *primary* trabeculæ are merely direct *on*-growths of the parachordals; the cornua trabeculæ are *out*-growths of the trabeculæ.

The intermediate element, or intertrabecula, is a fresh outbreak, so to speak, of the median mesoblast of the axis, which is tubular, behind, where it encloses the notochord, but, re-appearing in front, beyond it, it shoots forth as a *solid process* of the skeletal axis.

Close to the fore end of the primary trabeculæ there arises a similar but rather smaller bar, and the two parts are so close together that they chondrify continuously; these side bars are the palatine cartilages, evidently rudimentary structures.

Here they are not distinct from the long spur (pterygoid cartilage), which shoots forwards from the dorsal element (suspensorium) of the mandibular arch; this is like what we see in the Tadpole, but unlike that which is found in Skates, Teleosteans, and Urodeles. Thus, with the palatine included, the suspensorium here is a *palato-quadrate;* in the Skate, Teleostean, and Urodele the suspensorium is a *pterygo-*

quadrate. As in the Tadpole, the fore end of this bar is fixed; as in the Teleostean Urodele, and adult Frog, the hind part, or pedicle, is free.

As in the Tadpole, the suspensorium is sub-parallel with the axis of the skull, and the free mandible (MECKEL'S cartilage) grows forwards and inwards; that condition is temporary in the Batrachian, it is permanent in *Lepidosteus*.

As to the development of the basal bands of the skull, this type agrees with the Selachians and Teleosteans (*Salmo*) in the synchronism of the *para-* and *pro*-chordal tracts; but in Batrachians, Urodeles, and Marsipobranchs, the *trabeculæ are developed first;* they embrace the fore end of the notochord closely, and are both *para-* and *pro*-chordal; afterwards the hinder parachordal region is chondrified, separately in Urodeles, and continuously in Batrachians and Marsipobranchs.

The development of the complex hyoid arch is very different in this *Holostean* Ganoid, and in the *Chondrostean* Sturgeon, from what we find in Teleosteans, Batrachians, and Urodeles.

In the Salmon the primary bar breaks up into two long bands, with a short segment below; the foremost is the larger, retains its connexion with the ear-capsule, widens above as the hyomandibular, and narrows, antero-inferiorly, as the symplectic region.

The narrower, hind band becomes postero-inferior in position, keeps the small distal segment, and acquires a new, small segment, above, by which it becomes attached to the space between the hyomandibular and symplectic; the *late*, small upper segment is the inter-hyal, the long bar the epi-ceratohyal, and the short, distal segment the hypo-hyal.

In the lowest Urodele, *Proteus*, the hyoid arch is composed of two massive segments, one short, the upper or hyomandibular, and the other, the long, lower bar, the cerato-hyal; this is like that which obtains in Sharks.

In the larger Urodeles (*Menopoma, Cryptobranchus*) there is but little difference (apparently) in the time of development of the segments, but the upper part breaks up into two segments corresponding to the hyomandibular and symplectic segments in the Sturgeon; the cerato-hyal is large, and the hypo-hyal breaks up into three pieces.

In many of the Caducibranchiate Urodeles, and in some kinds of Anura (*Salamandra, Triton, Pseudophryne, Bombinator*), all but the uppermost part of the hyoid arch is suppressed; but in the Batrachia, generally, it is developed, as *two, three,* or even *four* segments; these, with the exception of the uppermost, as a rule, do not appear until two or three months after transformation, and are only developed in the Tadpole in rare cases, as in *Pseudis* and *Pipa*.

In *Lepidosteus* and in *Acipenser* the formation of the segments of the hyoid arch takes place at once during chondrification; *Lepidosteus* has the same number of cartilages as the Teleostei, but *Acipenser* has a distinct symplectic piece—a kind of segmentation which is not equivalent to the subdivision of the upper part of a branchial arch into a *pharyngo-* and an *epi*-branchial, but the epi-hyal is segmented at its distal fourth.

The basi-hyal of *Lepidosteus* is remarkable for being very long and essentially double. There are only four perfect and one imperfect branchial arches; the auditory capsules, at first, are as distinct as in the Tadpole, their basal region remains membranous for a good while, as in the Salmon.

In embryos two-thirds of an inch in length, more than one-half larger than our first stage, the chondrocranium is larger and stronger, but has few fresh things in it.

The trabeculæ and palato-quadrate cartilages are still confluent, but the former are now some distance apart, the binding cells of the former stage being converted into a pyriform mass of true cartilage, with its broad end in front and projecting beyond the paired bands or trabeculæ; this is the intertrabecula. The pedicle of the suspensorium has applied the inner side of its apex to the most curved part of the trabecula, and an oblong joint is forming.

A spike of cartilage has grown forwards from the auditory capsule over the hinder part of the superorbital region; this structure is seen temporarily in large larvæ of *Triton*, and permanently in *Siren*.

The divergence of the basal bands is now at its fullest, and the apex of the cranial notochord—one-third of the rod—is twisted, curves a little upwards, and is far from the moieties of the investing mass.

In young *Lepidostei*, one-half larger than the last (1 inch long), the chondrocranium may be said to be complete, and free from intrinsic ossification, except in the sheath of the notochord, the cerato-hyal, and some parts of the branchial arches.

The whole structure is much longer, but most of the increase in length is due to the development of the three basal cartilages in front of the cranial cavity. The occipital arch is perfect, and the tegmen from it runs well forward.

The superorbital band is now perfect, and in front it passes into an anterior tegmen round the olfactory lobes, and the hemispheres, thus the cranial box is perfect there. But there is a large pyriform fontanelle below, a larger oval fontanelle on each side in the orbital region, and a still larger membranous space, the great fontanelle, above.

The sudden and immense development of the precranial bars in so short a time is very remarkable; their relative massiveness makes this skull like that of a young Sturgeon five or six times as large. In that type the solid rostrum is formed of the two large trabecular cornua, which flank the still larger intertrabecula, like decurrent leaves. In the Sturgeon there is an antorbital expansion of the lateral ethmoidal region at the end of the rostrum, and each olfactory capsule lies close in front of the antorbital wall, as in a crypt. But in *Lepidosteus* the two capsules are carried away to near the end of the snout, and have no cartilage near them except the rostral bar, on each side of which they lie.

Whilst the fore part of the chrondrocranium is like that of a young Sturgeon 5 or 6 inches long, the cranium proper is like that of a Salmon ten or twelve days after hatching, when its length agrees with that of this stage of *Lepidosteus*, namely, about 1 inch.

In the Salmon "fry" there is a hinder and a front tegmen cranii, a pair of super-orbital bands running from the auditory capsules to the anterior tegmen, a largely open roof between, open orbito-sphenoidal spaces, and an open pituitary fontanelle. Moreover, this is the "norma" according to which the skull of *Polypterus* is formed; but of course during growth it becomes more solid, and partly ossified.

The suspensorium suggests a very mixed relationship in this type; it runs forwards, parallel with the skull, as in the Tadpole, but its pedicle is now well articulated with a basipterygoid process as in the metamorphosed Frog, and more clearly than in that type prefigures the cranio-facial relation of the Sauropsida, where, as in Lizards and many Birds, the pterygoid portion of the suspensorial apparatus articulates with a basipterygoid outgrowth of the skull. The open orbito-sphenoidal spaces are seen again in Batrachians, *e.g.*, in *Acris Pickeringii* and *Rappia bicolor*.

The palatine portion of the suspensorium (or palato-quadrate cartilage) loses its ethmoidal conjugation, but retains its continuity with the pterygoid cartilage. The primarily and permanently separate palatine of the "Siluroids" runs forwards in the same manner, with no ethmo-palatine joint, such as is seen in the Salmon.

In adult Batrachians of the genus *Bufo* the continuity of the palatine cartilage is lost both with the ethmoid and the pterygoid cartilage, but it articulates with the former by a raised process as in the Salmon. The small size of the hyomandibular of *Lepidosteus*, and its distance from the mandibular pier, prepare us for the transformations of that part in the Batrachia where it becomes the "columella."

In a further stage, when it has doubled the size it had in the last instance—has become 2 inches long—the young *Lepidosteus* has fairly attained to its own characteristic type of skull, and most of the very limited osseus centres are now apparent. All the fore face is now greatly drawn out, twice as much as in the last, and the suspensorium, mandible, and lingual cartilages, have shot on forwards in like manner. The membranous spaces are only different from the last by the upper fontanelle being relatively less, and neatly circular, whilst the lower space is being divided by a *late* and *feeble* "post-pituitary" bar with a large anterior, and a small posterior space. But the type of skull seen in the young "fry" of the Salmon, and in such minute arrested Frogs as the Nearctic *Acris Pickeringii*, and the Australian *Rappia bicolor* and *Camariolius tasmaniensis*, is not departed from, nor, indeed, will be.

But even what is seen in young *Lepidostei* 2 *inches* long scarcely prepares us for what we find in specimens a little more than twice that size. At this stage, as in Sawfishes (*Pristis*), this prenasal cartilage (intertrabecula) has become *three times* as long as the whole cranial cavity, and *six times* as long as its associated cornua trabeculæ—now mere delicate leafy appendages to its base. The cranium proper has not altered in any important degree since the last stage, but the bony centres are nearly all there; all those that are seen in the Salmon, or in Teleostei, generally are found, with the exception of the super-occipital and a bone not found, I believe, in the Ganoids, namely, the "pterotic;" its suppression is correlated with the development of a special

temporal scute over the same region; the "squamosal," a bone only, exceptionally present in the Teleostei among the Siluroids.

The post-pituitary band of cartilage, a feeble promise of the solid post-clinoid wall of the "Amniota," is now complete. Some things characterising this type are now well seen, namely, the small lateral ethmoidal bone in the thin, closing-in, skull wall, without any prefrontal (ali-ethmoidal) wing, the double "articular" centre, and the huge coronoid crest to the articulo-Meckelian rod; these two latter characters are also seen in *Amia calva*, as shown by Professor BRIDGE.

The very small size of the preoperculars, the form and size of the interopercular, which here so strongly resembles the preopercular of the Teleostei, are very noticeable in this skull, as also the long chain of bones interspersed between the "os mystaceum" or edentulous maxillary and the premaxillary.

The adult condition of the skull in *Polypterus* and *Amia* (TRAQUAIR, Jour. of Anat. and Phys., vol. 5, plate 6, pp. 166–182; and BRIDGE, ibid., vol. 9, plate 23, pp. 605–622) presents so many things, both in likeness and contrast, that they must be noticed in conclusion.

In *Polypterus*, as in *Lepidosteus*, the four fontanelles are permanently open; the basioccipital projects far beyond the oblique foramen magnum, and the occipital bone is single, made up evidently of a basal and two lateral pieces, without a supraoccipital; then there are no pterotics, and the olfactory capsules are sub-terminal. But in this type there are no epiotics distinct from the opisthotics.

There is a large sphenotic bone, right and left, which takes up the antero-posterior sphenoidal regions and part of the lateral ethmoidal, besides which there is a pair of lateral ethmoidals which project outwards, and an ethmo-septal bone in front.

The metapterygoid in *Polypterus* is far from the skull, in which there are no basipterygoid processes; the palatine is a small ectosteal bone; the hyomandibular has only one centre; and the preopercular is continuous with the squamosal, as in the Amphibia; there is no interopercular.

But *Amia calva* has a skull which comes much nearer to that of *Lepidosteus* in several respects, but the lateral and inferior fontanelles are filled in, in this solid skull, which comes nearer that of the Physostomous Teleosteans.

The basioccipital projects behind the oblique foramen magnum; there is no supraoccipital, nor any pterotics, and the epiotics are distinct from the opisthotics.

It has a pair of bones which are not seen in *Lepidosteus*, namely, the orbitosphenoids; and its so-called prefrontals or lateral ethmoids project, as in the Teleostei. It has a distinct pedicle to the suspensorium, capped with cartilage, but not forming a definite joint with any distinct basipterygoid.

Its palatine cartilage is ossified both endosteally and ectosteally; and the whole palato-pterygoid is almost Teleostean in its solidity.

There is a large coronoid crest, and there are *two* articular bones on each side, as in *Lepidosteus*. There is a cartilaginous inter-hyal, articulated between a distinct

hyomandibular and symplectic; and the upper or styloid end of the cerato-hyal has, as in Osseous Fishes, a separate centre, whilst the hypo-hyal has *only one*, as in *Lepidosteus;* in Osseous Fishes it has *two*.

There are the four normal operculars; the "os mystaceum" is dentigerous and carries a jugal in its hinder half. Above the skull, the scutes, which seem to me to be a little misunderstood by Professor BRIDGE, correspond, in essentials, to those of *Lepidosteus*.

I should propose the term "azygous parietal" for his *dermo*-superoccipital; "squamosals" for his *parietals;* and "prerostral" for the azygous transverse bone, which, as in *Lepidosteus*, furnishes the snout in front, and which is called by him *ethmoid*. The olfactory capsules are sub-terminal, and the large *nasals*, which cover them by their notched fore margin, are evidently the nasals and "ethmo-nasals" of *Lepidosteus*, in one piece, right and left.

Amia is a true Ganoid, and it has several unmistakable diagnostics even in its skull; but it comes very near to the Physostomous Teleosteans.

DESCRIPTION OF THE PLATES.

Plate.	Fig.	Stage.		Number of times magnified.
30	1	1	Section of the head of an embryo of *Lepidosteus* 4 lines long	30
,,	2	1	A similar section of an embryo $4\frac{1}{2}$ lines long . .	30
,,	3	2	Chondrocranium of an embryo 5 lines long; lower view	36
,,	4	2	Section of the head of an embryo $5\frac{1}{2}$ lines long .	30
,,	5	3	Section of the head of an embryo $7\frac{1}{2}$ lines long .	$22\frac{1}{2}$
,,	6		The other half of the same head	$22\frac{1}{2}$
,,	7	3	Chondrocranium of an embryo $\frac{2}{3}$-inch long; lower view	30
,,	8	3	The same skull; upper view	30
,,	9	3	Head of same embryo; lower view	15
31	1–15	3	A series of vertically transverse sections through the head of an embryo $7\frac{1}{4}$ lines long	30
32	1	4	Chondrocranium of an embryo 1 inch long (nearly). Upper view	24
,,	2	4	The same object; lower view	24

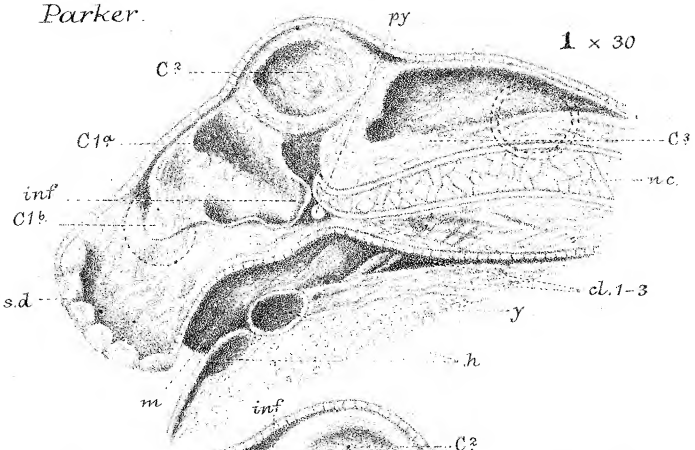
Plate.	Fig.	Stage.		Number of times magnified.
32	3	4	Part of basis-cranii of same skull; upper view. .	36
,,	4	4	Section of the head of an embryo of the same stage .	24
,,	5	4	Upper view of head of same stage. Seen partly as a transparent object	24
,,	6	4	Part of hyoid arch of same	24
33	1–13	4	A series of vertically transverse section of an embryo, 1 inch long (nearly)	27
,,	14–16	5	First three of a series of vertically transverse sections of a young *Lepidosteus* $2\frac{1}{2}$ inches long .	20
34	1	5	Dissection of skull of young *Lepidosteus*, 2 inches long; chondrocranium with some of the parostoses attached; upper view	12
,,	2	5	The same object; lower view	12
,,	3	5	Part of basis cranii of same skull; upper view . .	15
,,	4	5	Inferior arches of the same skull	12
35	1–12	5	4th to 15th of a series of vertically transverse sections of a young *Lepidosteus*, $2\frac{1}{2}$ inches long.	20
36	1–8	5	16th to 23rd of a series of vertically transverse sections of a young *Lepidosteus*, $2\frac{1}{2}$ inches long.	20
,,	9	5	Part of fig. 8	60
37	1	6	Skull of a young *Lepidosteus* 4 inches 5 lines long, with superficial bones *in situ*; side view . . .	6
,,	2	6	The same skull; upper view.	6
,,	3	6	The same; lower view.	6
,,	4	6	The inferior arches of the same skull; outer view .	$7\frac{1}{2}$
38	1	6	Chondrocranium of a young *Lepidosteus* 4 inches 5 lines long; upper view	$6\frac{3}{4}$
,,	2	6	Hind part of same; lower view	$6\frac{3}{4}$
,,	3	6	Part of basis-cranii of same; upper view . . .	$13\frac{1}{2}$
,,	4	6	Part of chondrocranium of same; upper view . .	$13\frac{1}{2}$
,,	5	6	Inferior arches of the same skull; inner view . .	$7\frac{1}{2}$

List of Abbreviations.

The Roman figures indicate nerves or their foramina.

ag. Angular.
al.s. Alisphenoid.
ar. Articular.
ar.c. Articular cartilage.
a.s.c. Anterior semicircular canal.
au. Auditory capsule.
au.f. Auditory fenestra.
b.a. Basilar artery.
b.br. Basi-branchial.
b.hy. Basi-hyal.
b.o. Basioccipital.
b.pg. Basipterygoid.
C^1. Fore brain.
C^2. Mid brain.
C^3. Hind brain.
c.br. Cerato-branchial.
c.hy. Cerato-hyal.
cl. Cleft.
cr. Coronoid.
cr.c. Coronoid cartilage.
c.tr. Cornua trabeculæ.
d. Dentary.
e. Eye.
e.br. Epi-branchial.
e.hy. Epi-hyal.
ep. Epiotic.
et.n. Ethmonasal.
f. Frontal.
fo. Fontanelle.
g.p. and *br.p.* Gill processes.
h. Heart.
h.br. Hypo-branchial.
h.hy. Hypo-hyal.
hm. Hyomandibular.
hm.c. Hyomandibular facet and condyle.
hm.f. Hyomandibular fenestra.
h.s.c. Horizontal semicircular canal.
i.hy. Inter-hyal.
inf. Infundibulum.
i.op. Interopercular.
i.tr. Intertrabecula.
j. Jugal.
l.eth. Lateral ethmoid.
m. Mouth.
m.c.g. and *m.g.* Mucous gland.
mk. Meckel's cartilage.
mn. Mandible.
ms.pg. Mesopterygoid.
mt.pg. Metapterygoid.
mx'., *mx.''* Maxillary.
my. Myelon.
n. Nasal.
nc. Notochord.
ol. Olfactory capsule.
op. Opercular and opisthotic.
op.p. Opercular process.
os.f. Orbito-sphenoidal fenestra.
ot.p. Otic process.
p. Parietal.
pa'. Superficial palatine.
pa.s. Parasphenoid.
p.br. Pharyngo-branchial.
p.cl. Posterior clinoid.
pd. Pedicle.
pg. Pterygoid.
pnl. Pineal gland.
p.ob. Preorbital.
p.op. Preopercular.
p.pg. Palato-pterygoid.
p.px. Palatine process of premaxillary.
pr.o. Prootic.

pt.o. Postorbital.
px. Premaxillary.
py. Pituitary body and space.
q. Quadrate.
q.c. Quadrate condyle.
s.ag. Supra-angular.
s.d. Sucking disk.
spl. Splenial.
s.ob. Supraorbital.
s.ob.c. and *s.ob.* Supraorbital cartilage.
s.op. Subopercular.
sp.o. Sphenotic.
s.t. Supratemporal.
su.ob. Suborbital.
sy. Symplectic.
t.cr. Tegmen cranii.
tr. Trabecula.
v. Vomer.
vb. Vestibule.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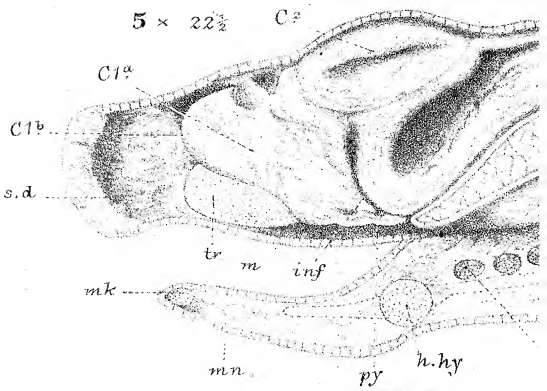
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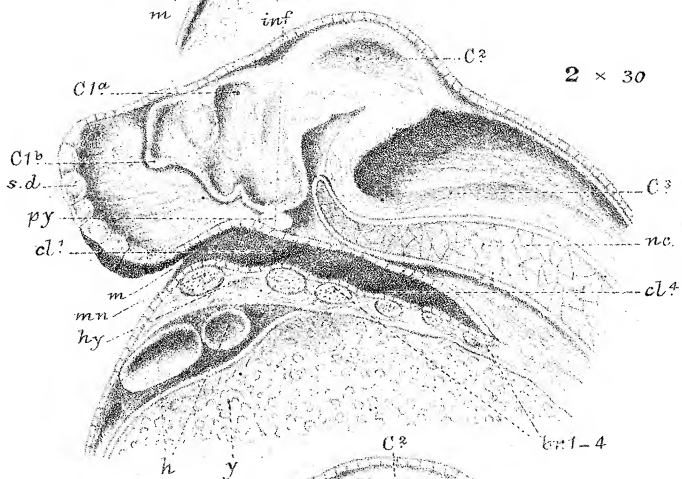
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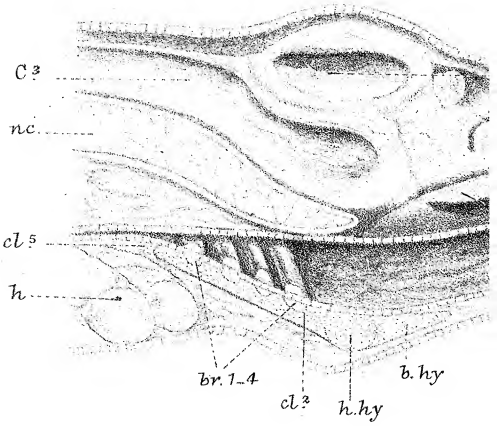
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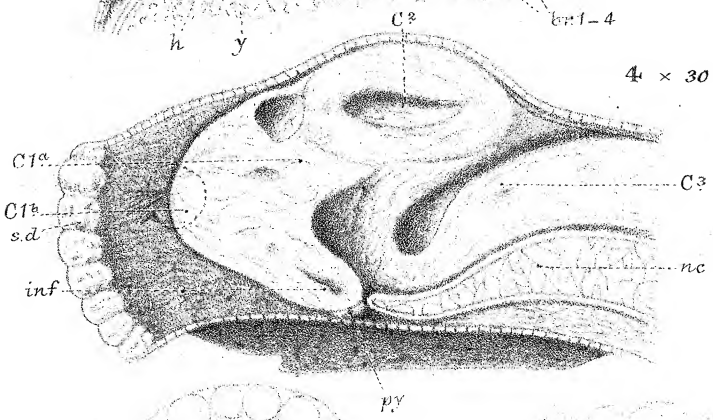
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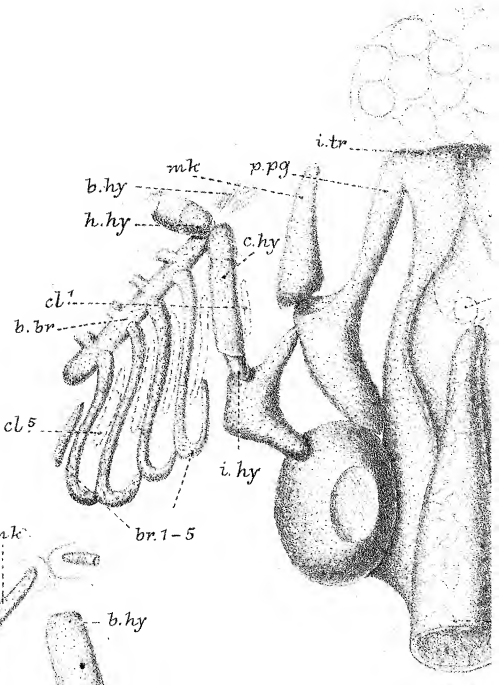
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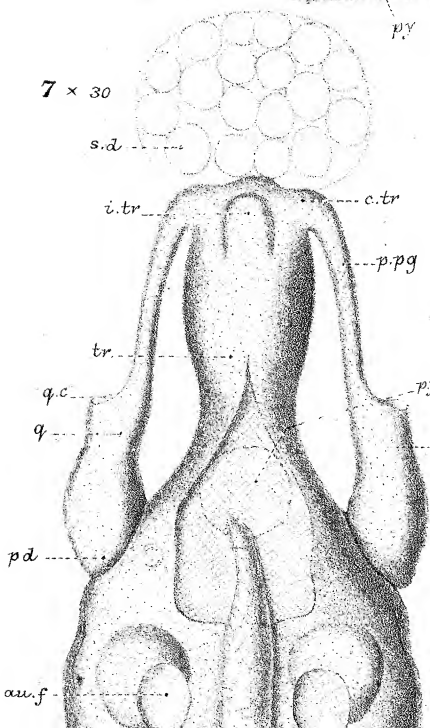
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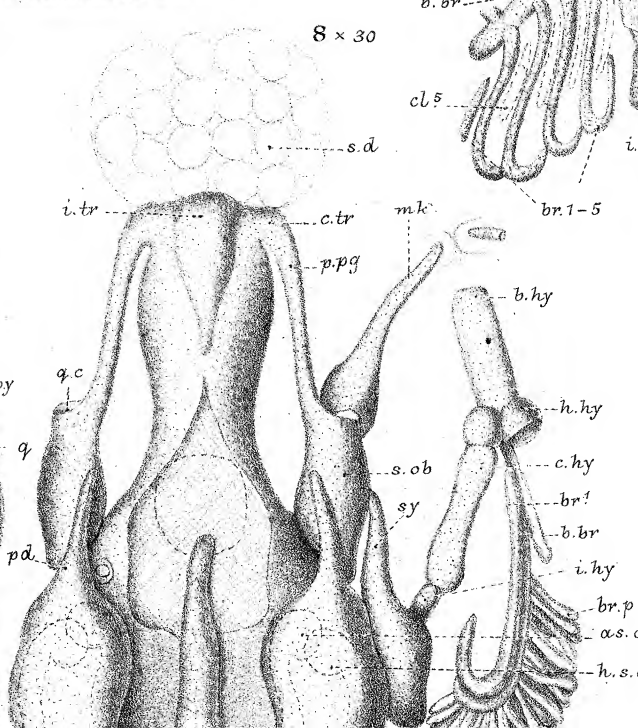
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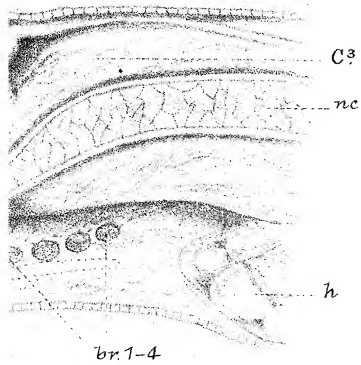
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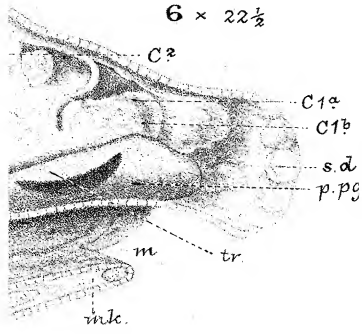
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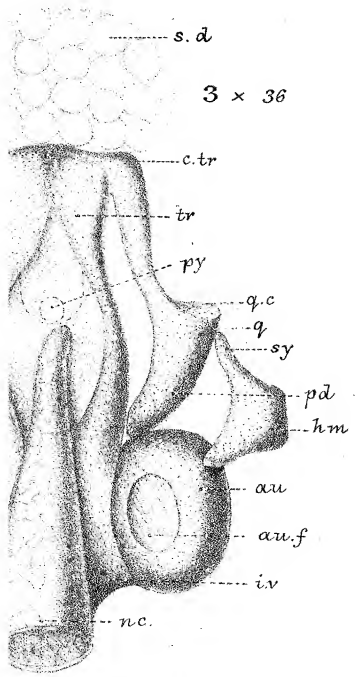
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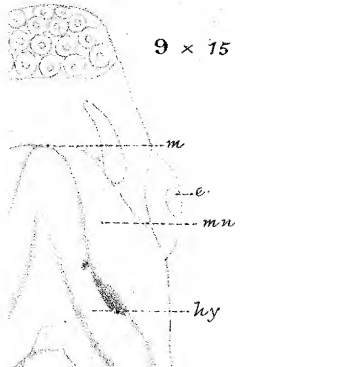
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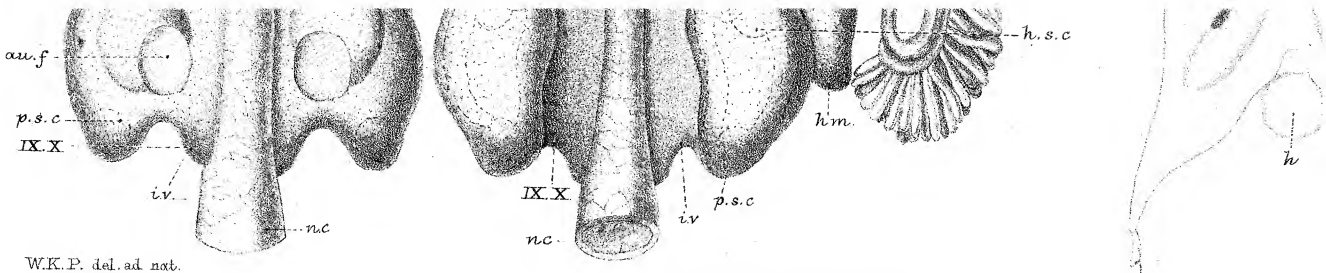
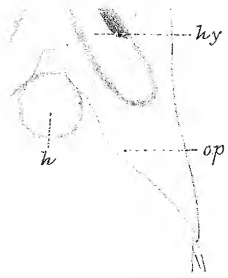


W.K.P. del. ad nat.
M.P. Parker lith.

LEPIDOSTEUS.



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W.K.P.& W.N.P. del.ad nat.
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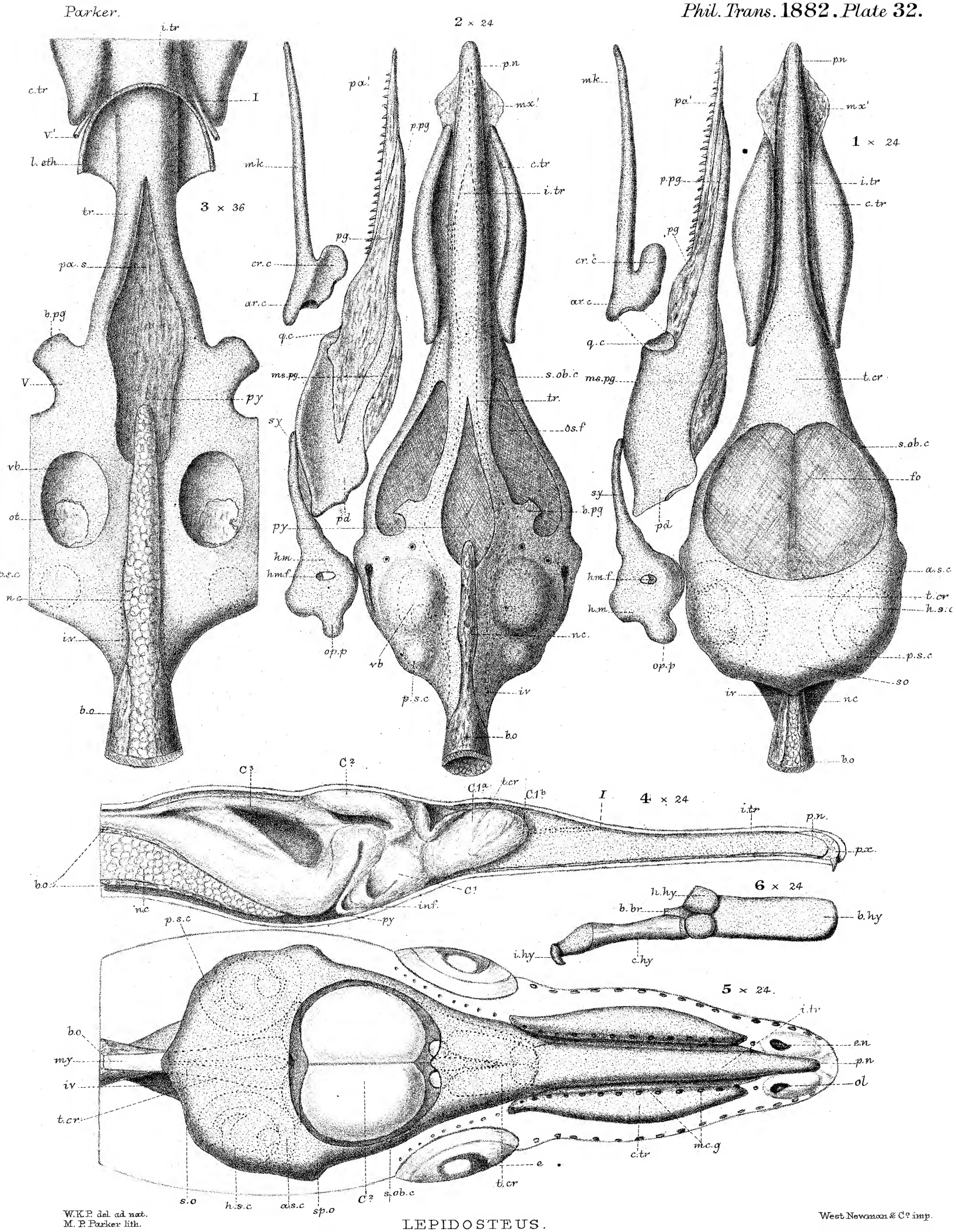

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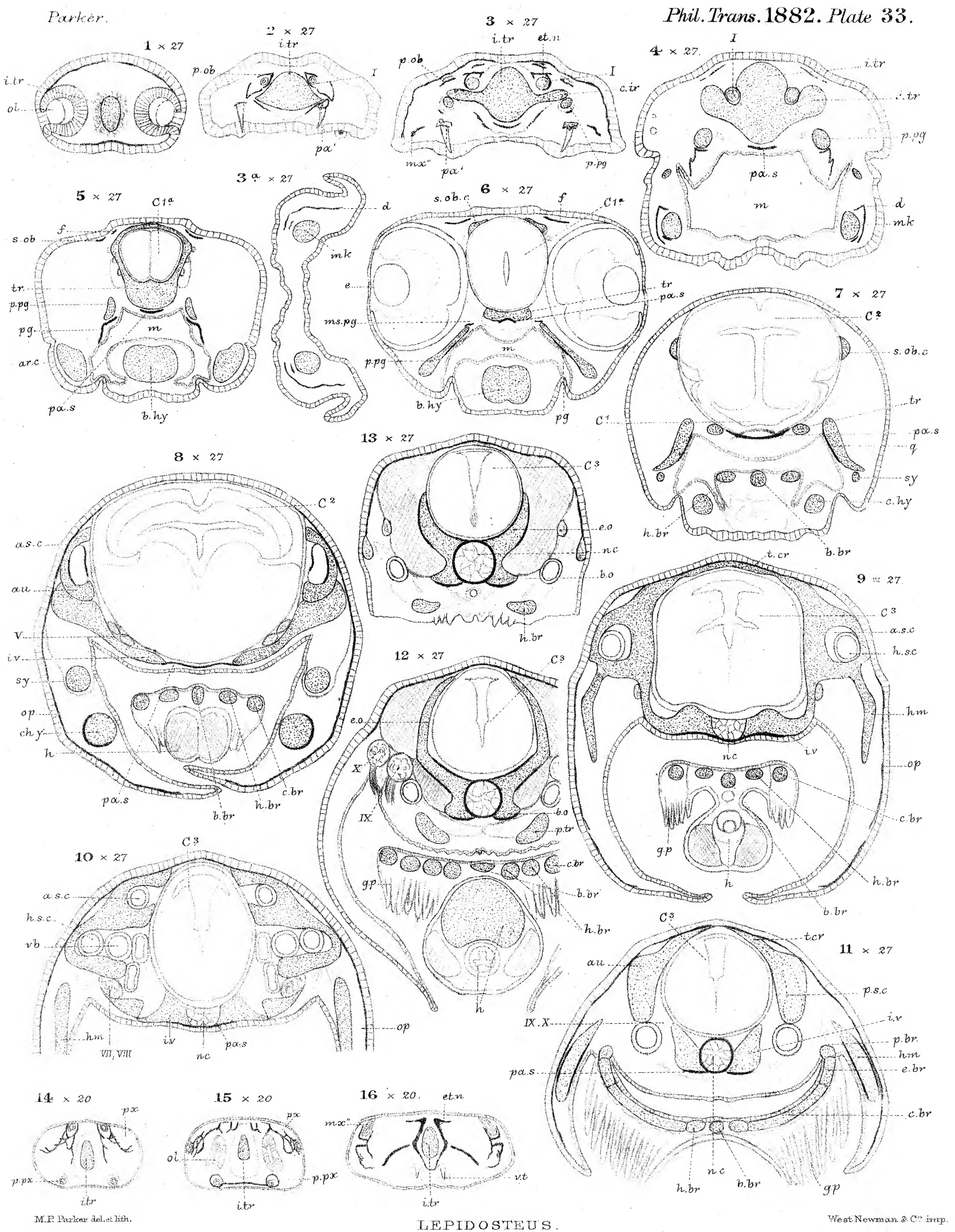

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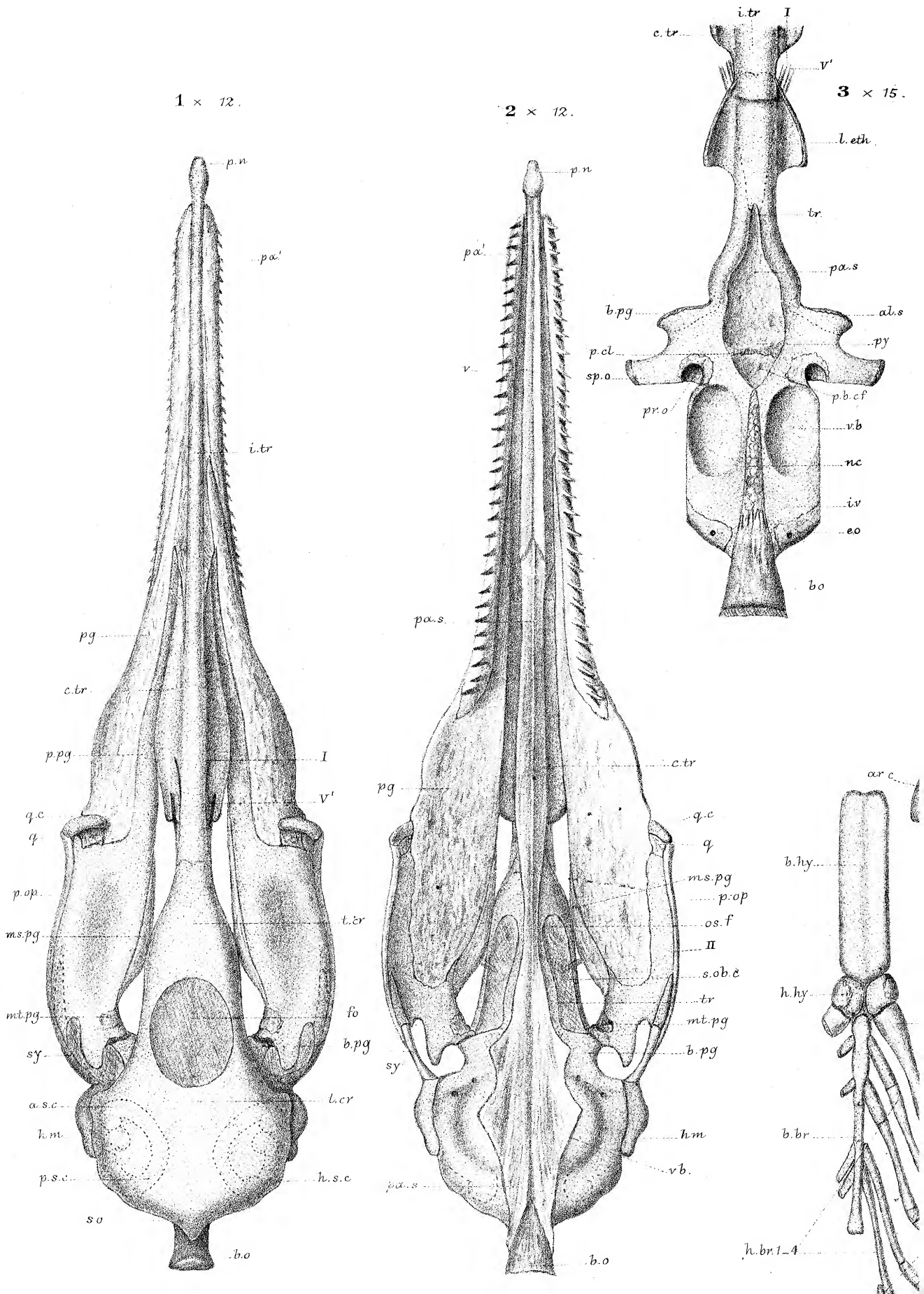
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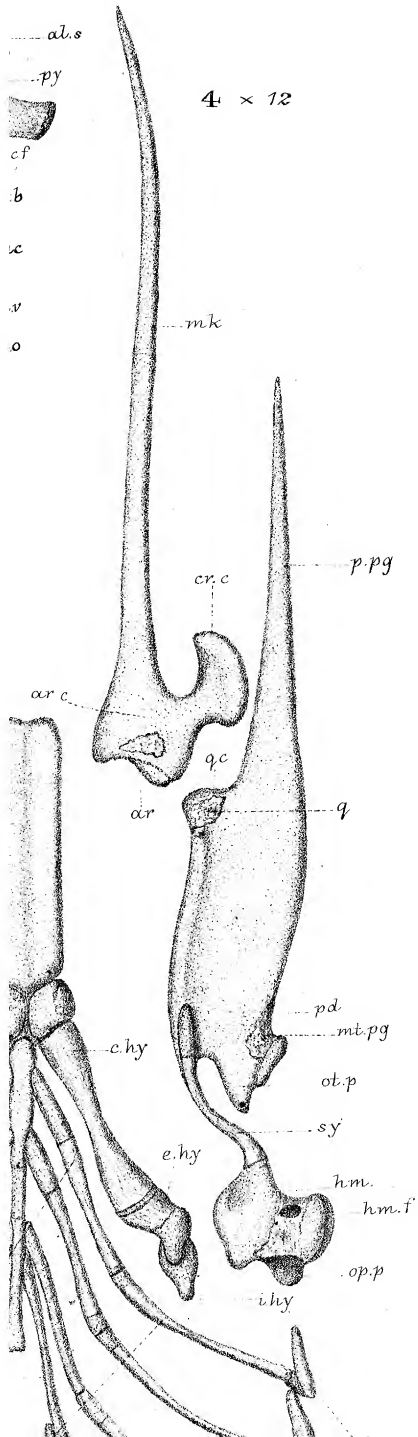
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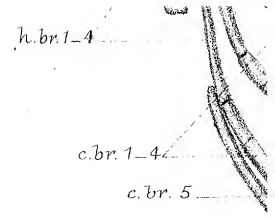
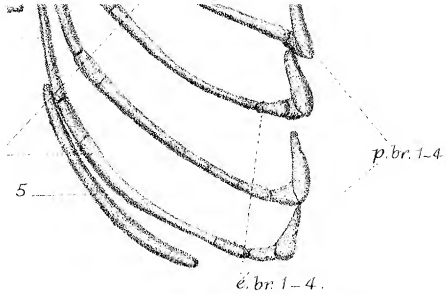


W.K.P. del. ad nat.
M.P. Parker lith.

LEPIDOSTEUS.



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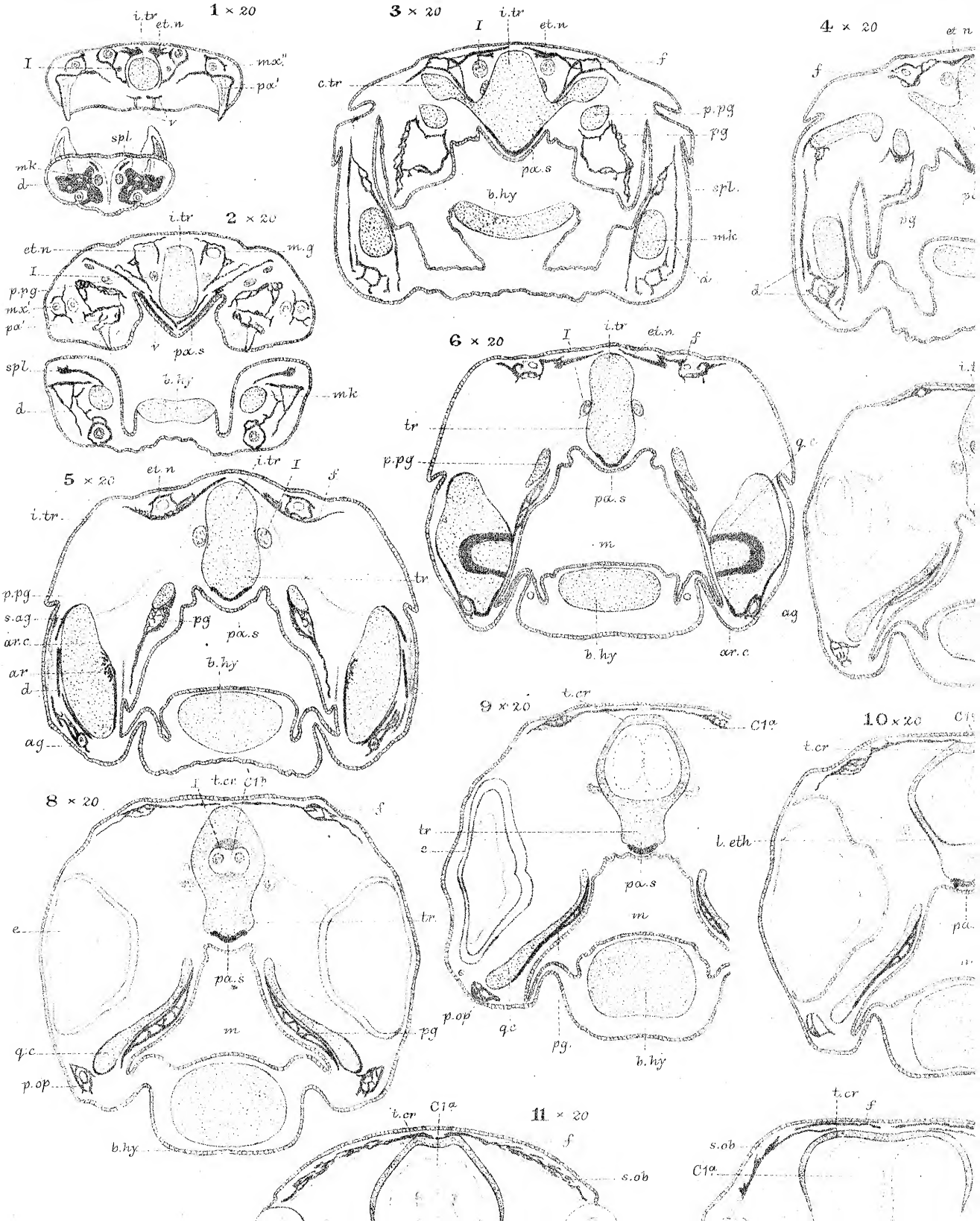
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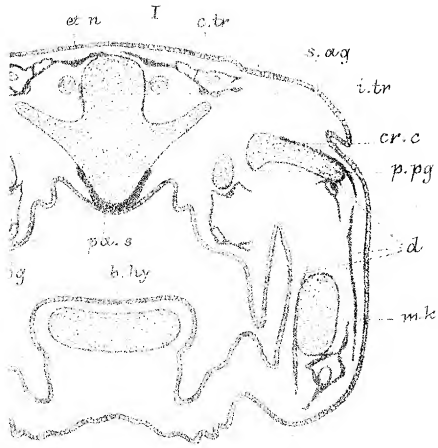
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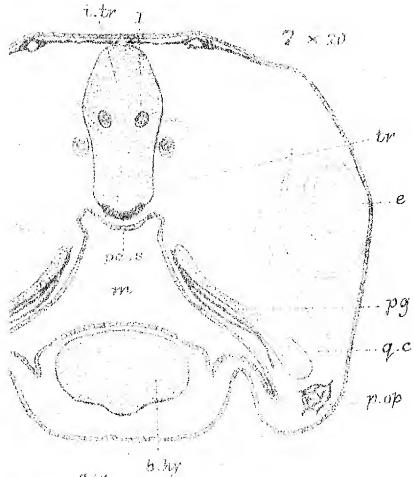
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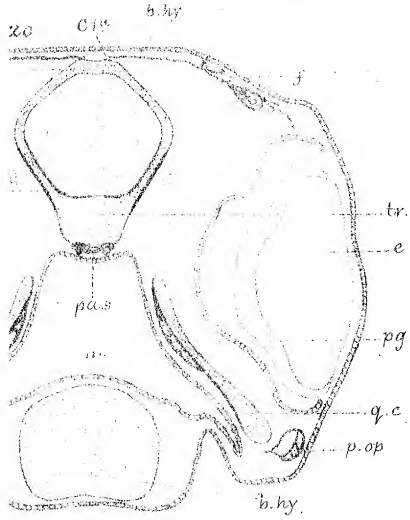
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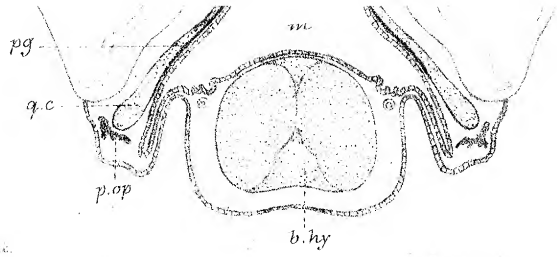
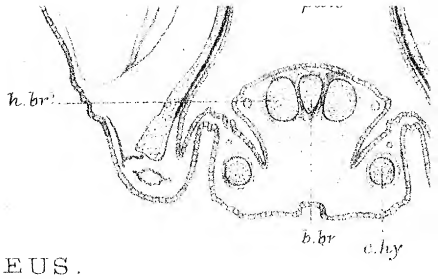
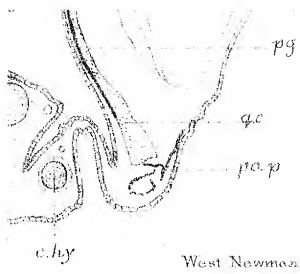


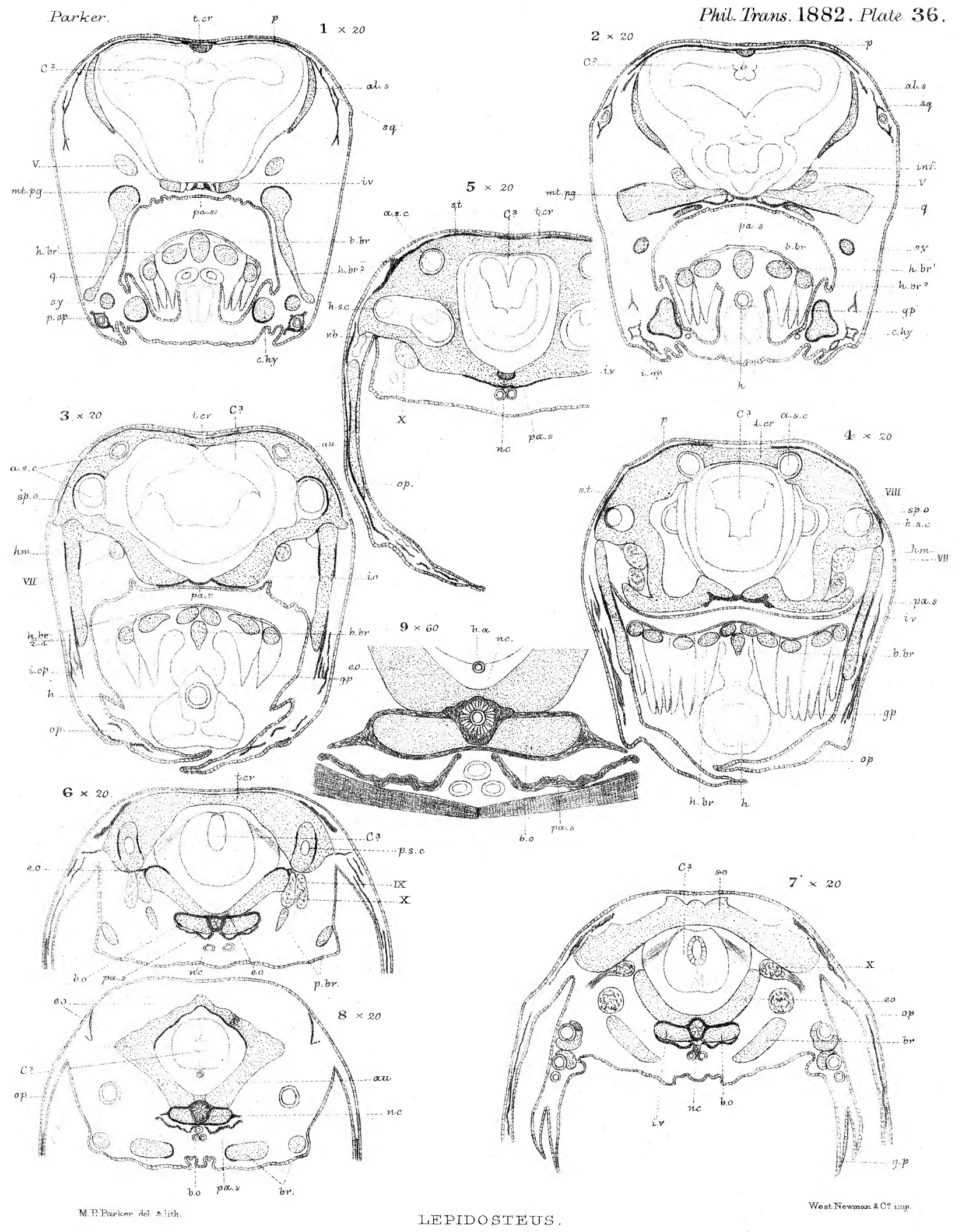


W.N.P. del. ad nat.
M.P.Parker lith.

LEPIDOSTEUS.



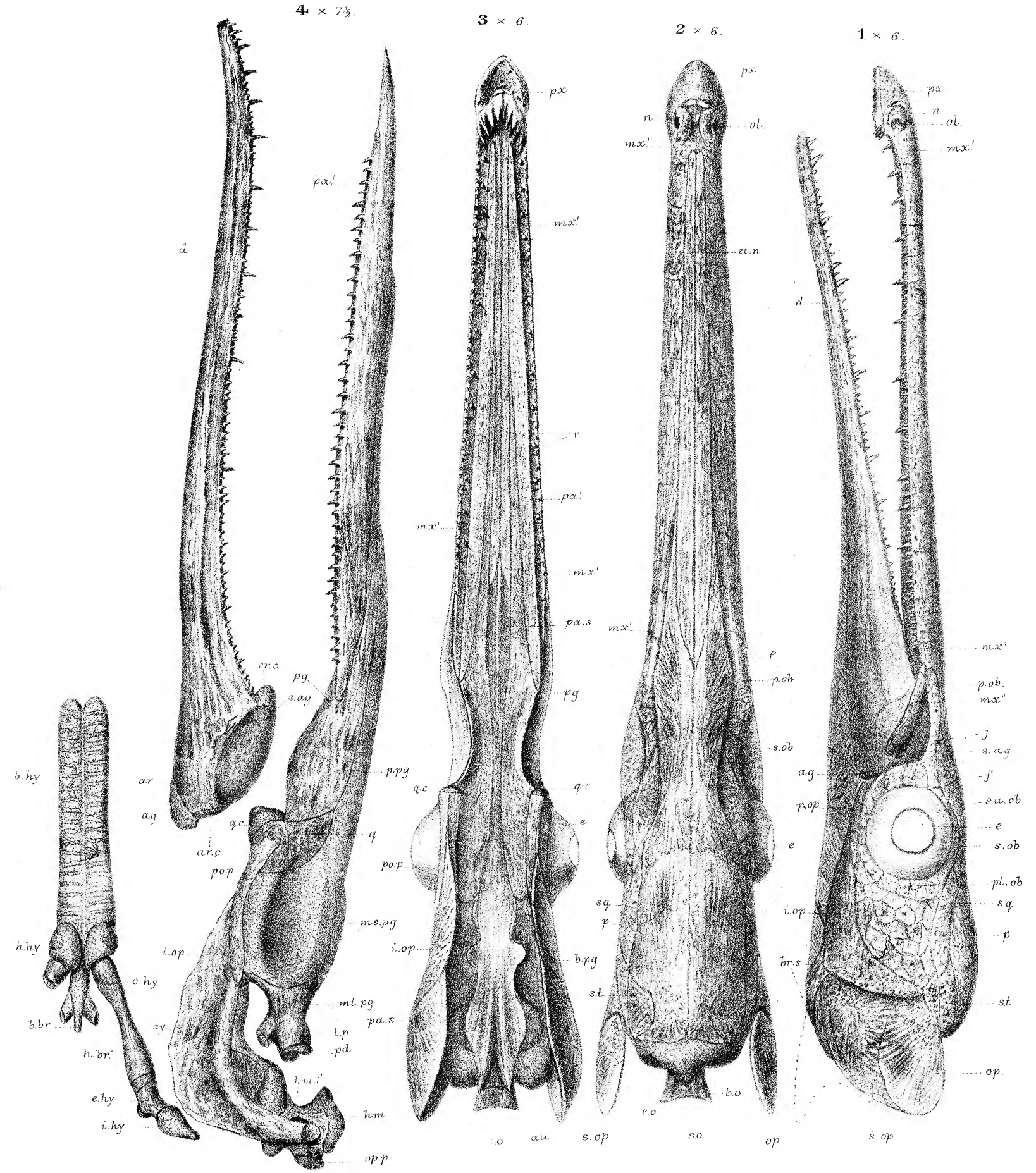
West Newman & Co. imp.



M.P.Parker del. & lith.

LEPIDOSTEUS.

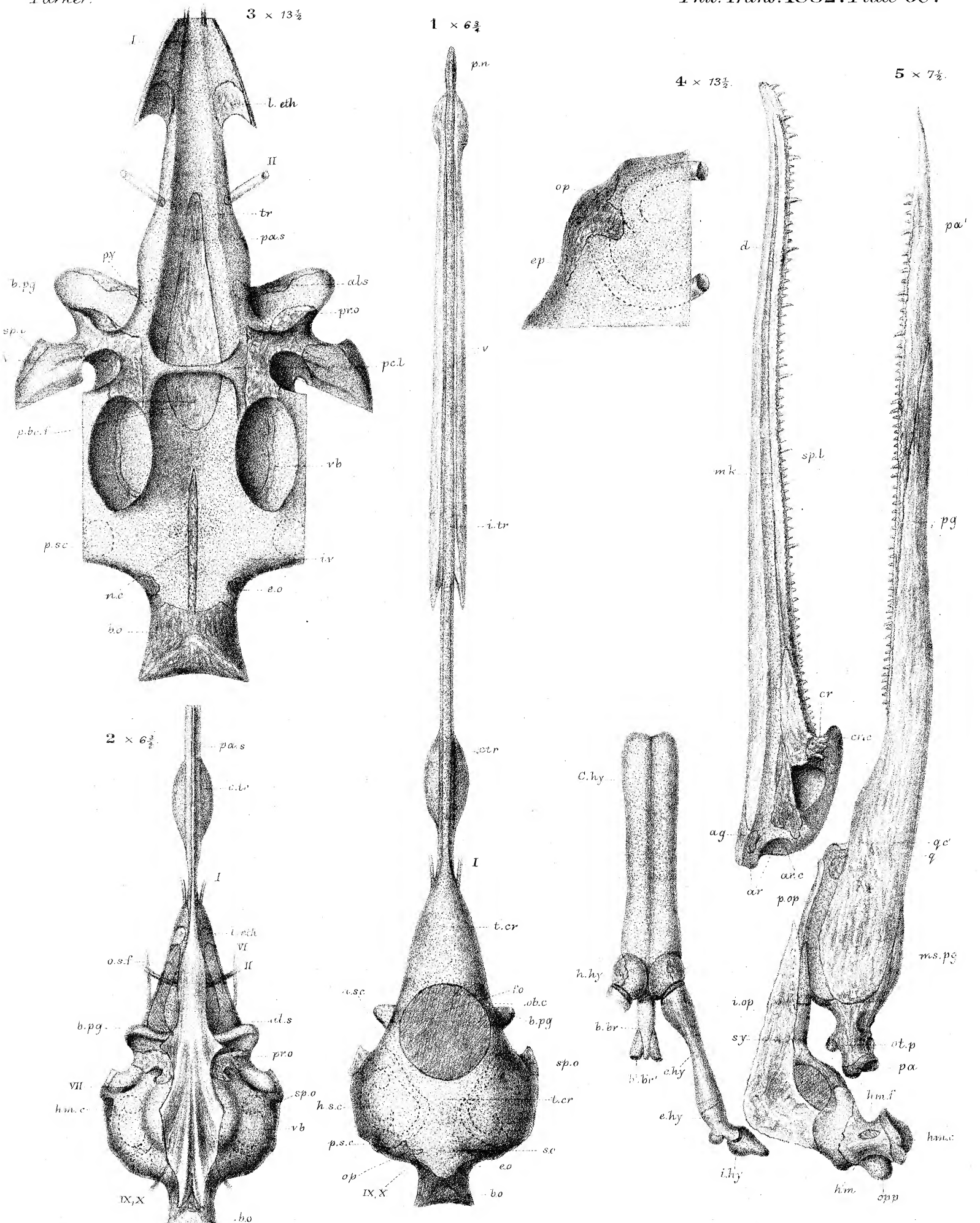
West, Newman & Co.ª imp.



W.K.P. del. ad. nat.
M.P. Parker lith.

LEPIDOSTEUS.

West Newman & Co. imp.



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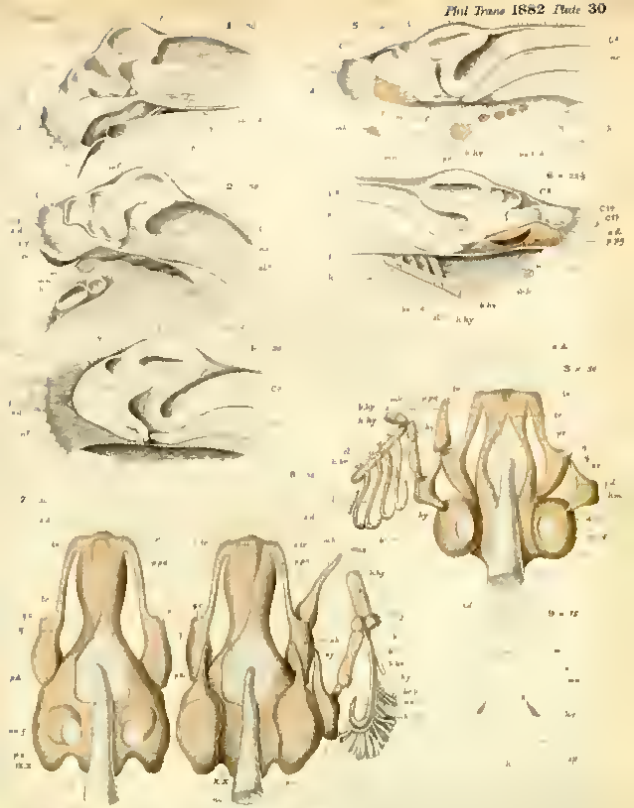
M. P. Parker lith.

West, Newman & Co imp.



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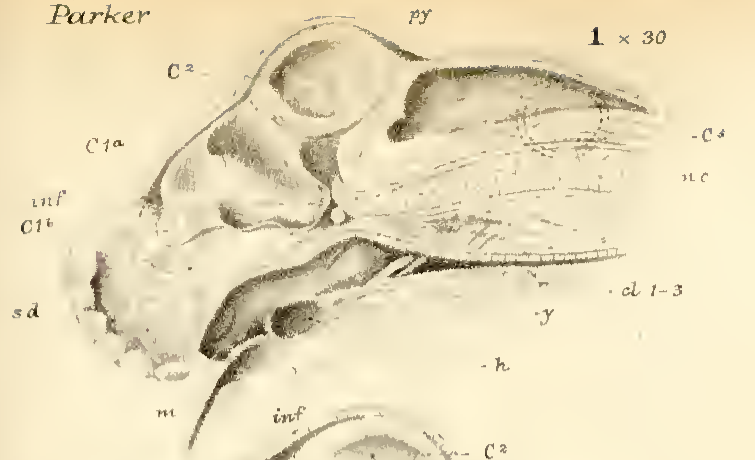
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py
C2
C1a
C1b
inf
sd
C3
nc
cl 1-3
y
h
m
inf

5 × 22½
C2
C1a
C1b
sd
tr
m
inf
mk
mn
py
h hy

2 × 30
C2
C1a
C1b
sd
py
cl 1
C3
nc
cl 4
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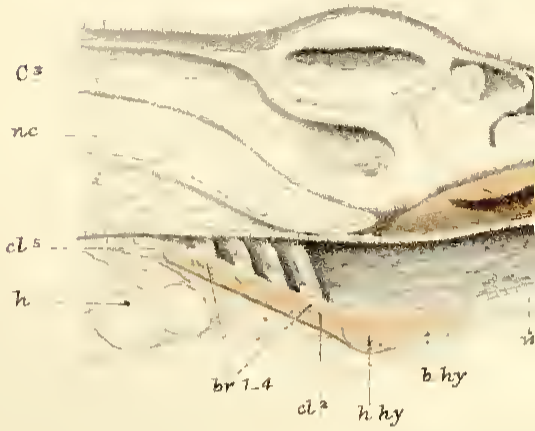
br 1-4
h
y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nc
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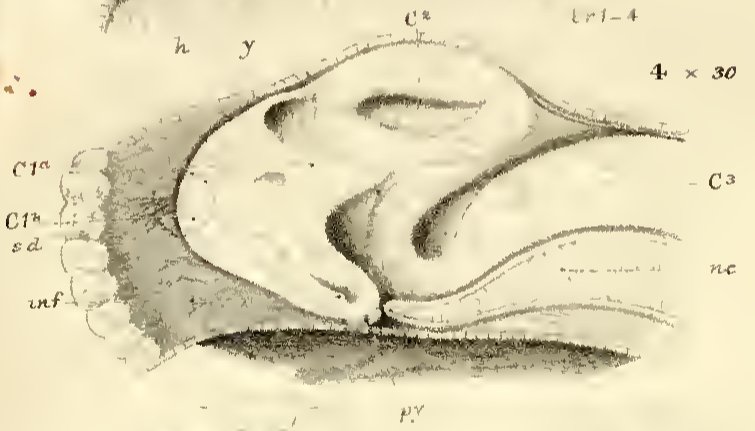
br 1-4
cl 2
h hy
b hy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C1a
C1b
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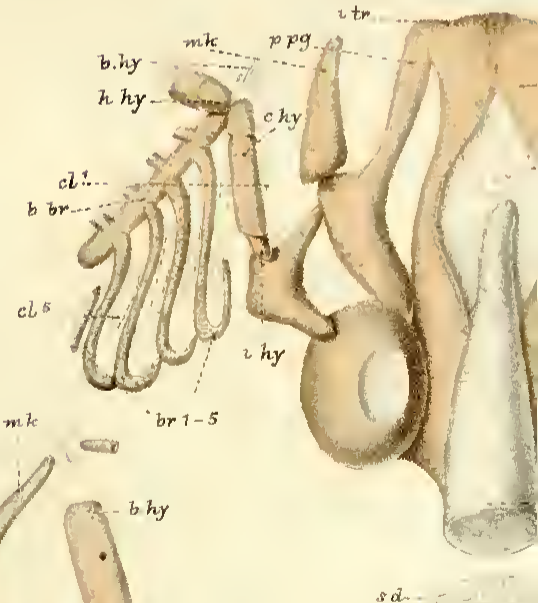
inf
C3
nc
py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mk
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b.hy
h hy
c hy
cl 1
b br
cl 5
i hy
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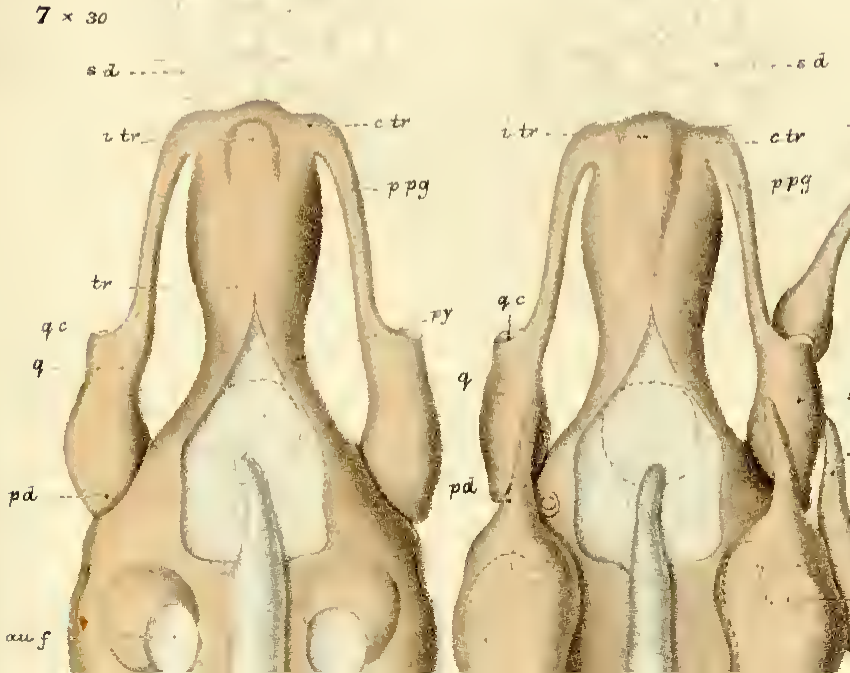
sd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sd
i tr
c tr
p pg
tr
qc
q
py
pd
axu f
mk
b hy
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br 1
b br
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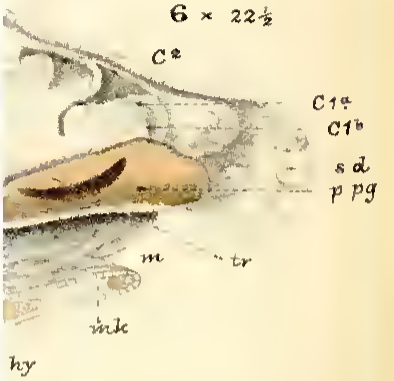
br p
as c
h s c

C3
nc
h
br 1-4

6 × 22½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C1a
C1b
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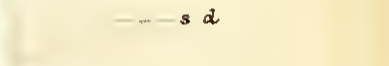
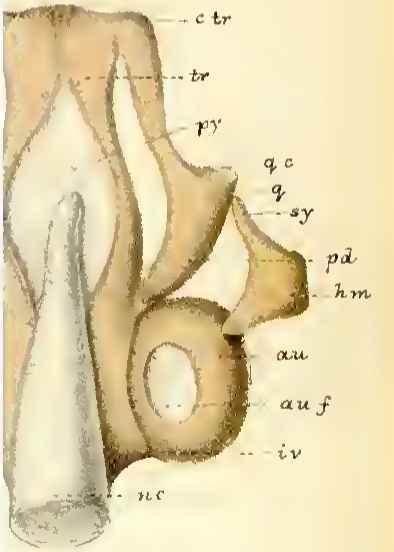

s d

3 × 36


c tr
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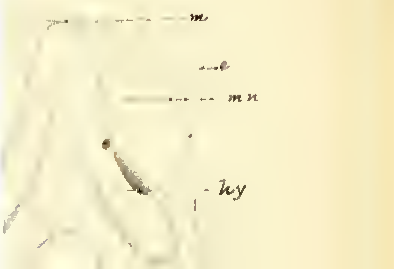
9 × 15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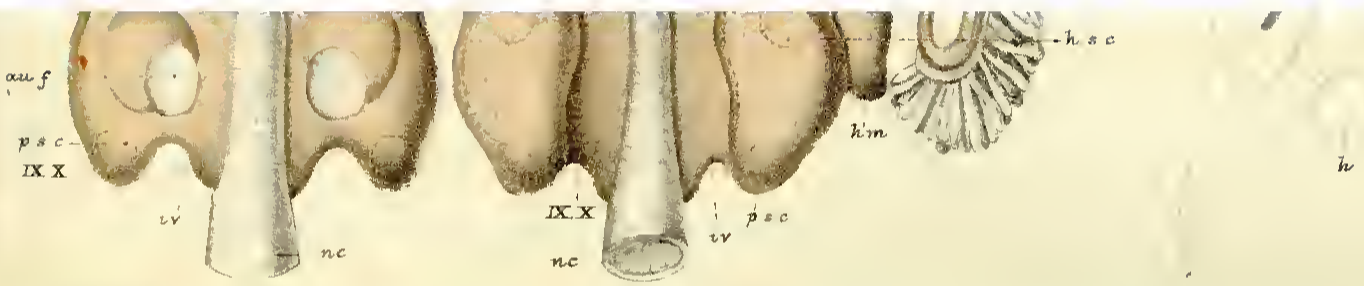
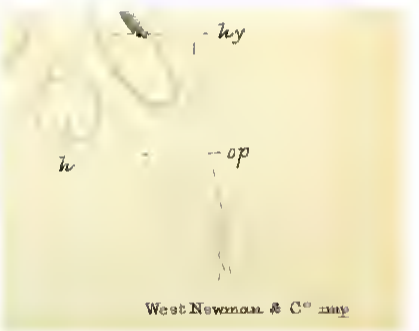


W.K.P. del. ad. nat.
M. P. Parker lith.

LEPIDOSTEUS.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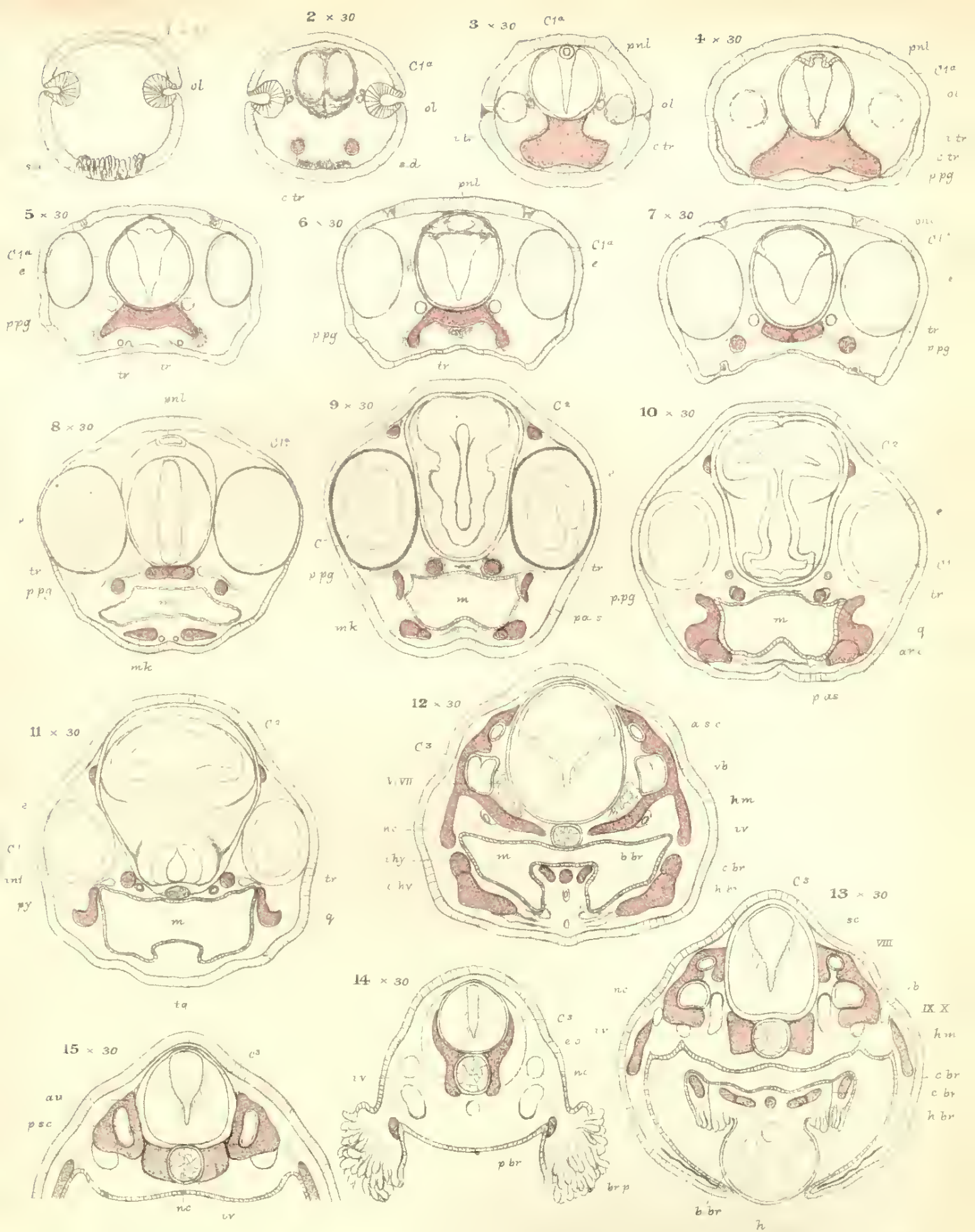
op
West Newman & Co imp



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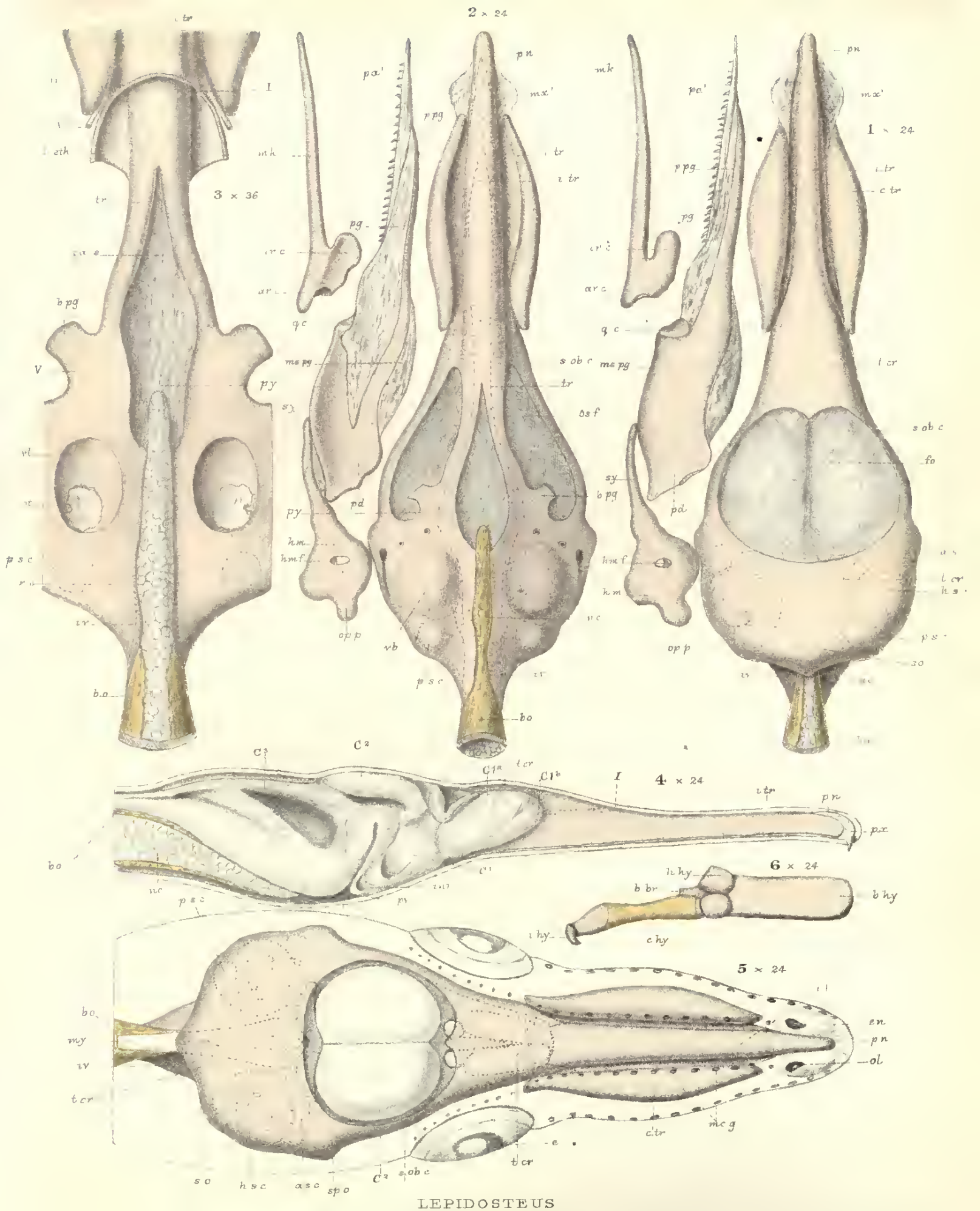

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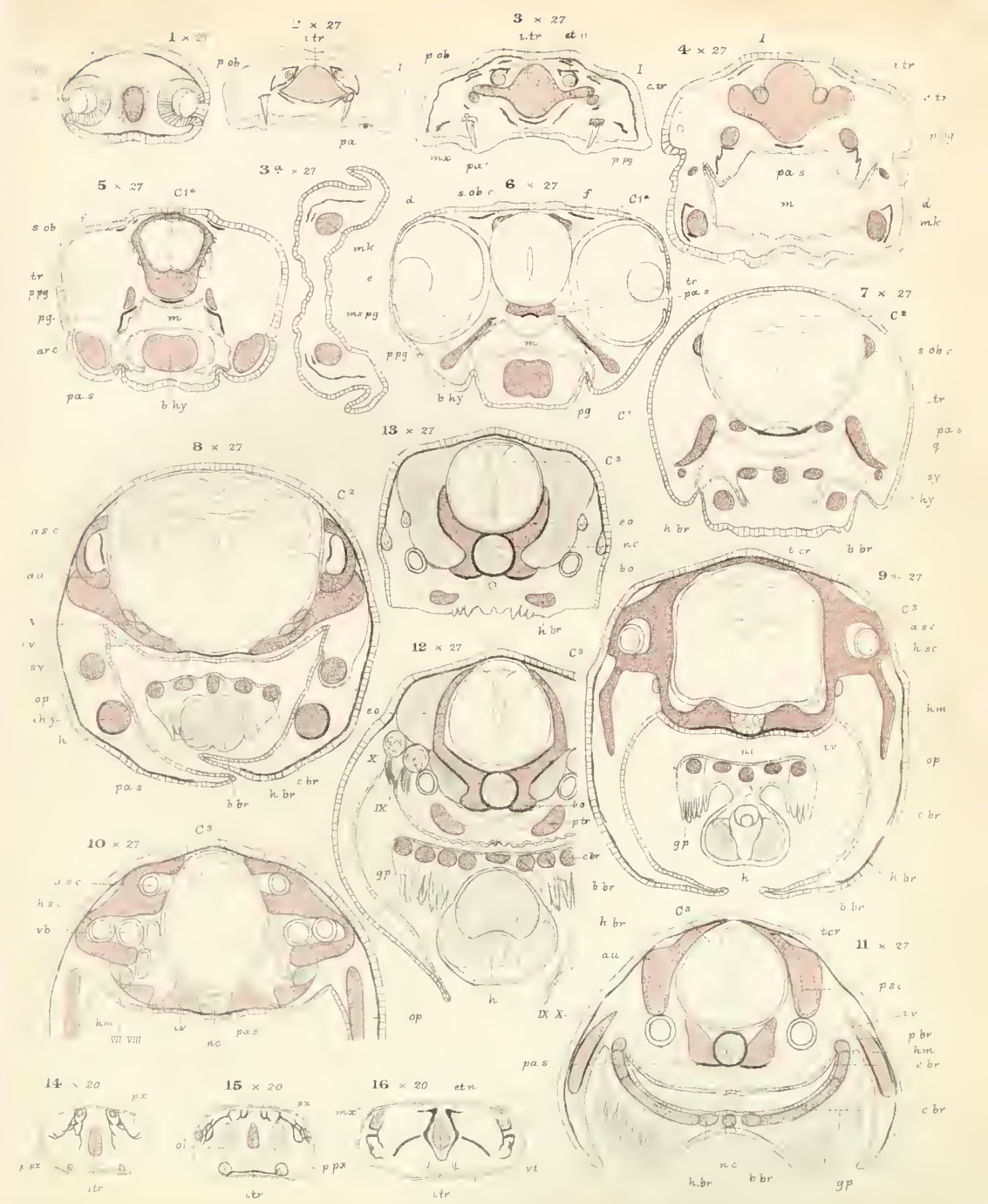

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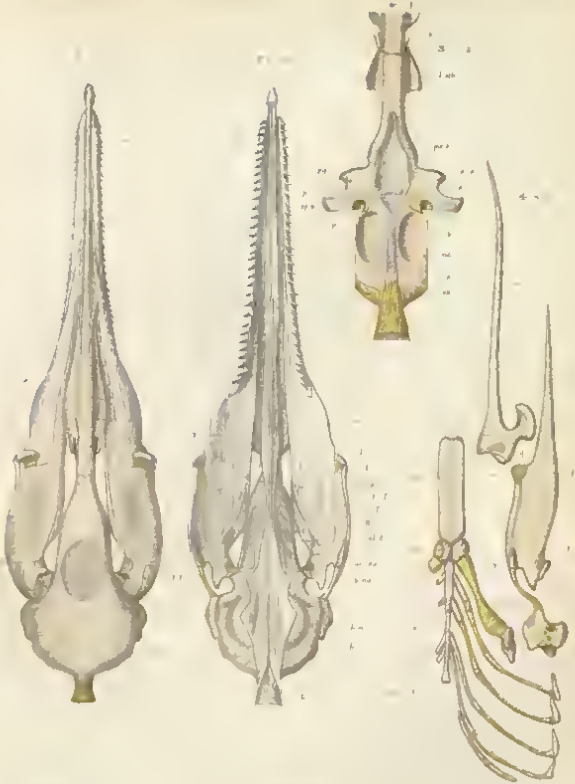

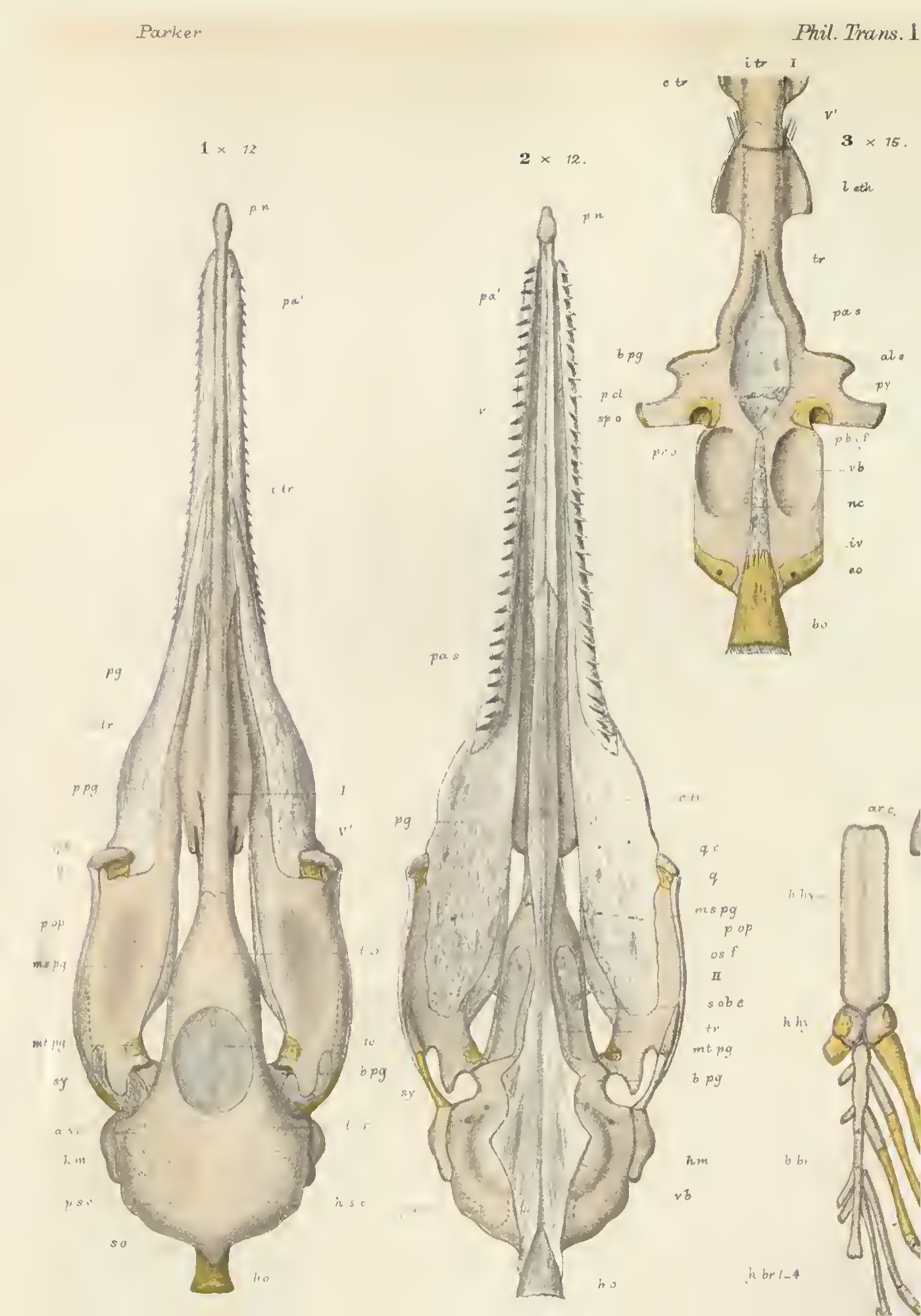
1 × 12
2 × 12.
3 × 15.
p n
pa'
i tr
pg
tr
p pg
I
V'
p op
ms pg
mt pg
sy
b pg
h m
p s c
h s c
so
bo
p n
pa'
v
pa s
pg
c tr
q c
q
ms pg
p op
os f
II
s ob c
tr
mt pg
b pg
sy
hm
vb
bo
i tr
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c tr
V'
l eth
tr
pa s
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p cl
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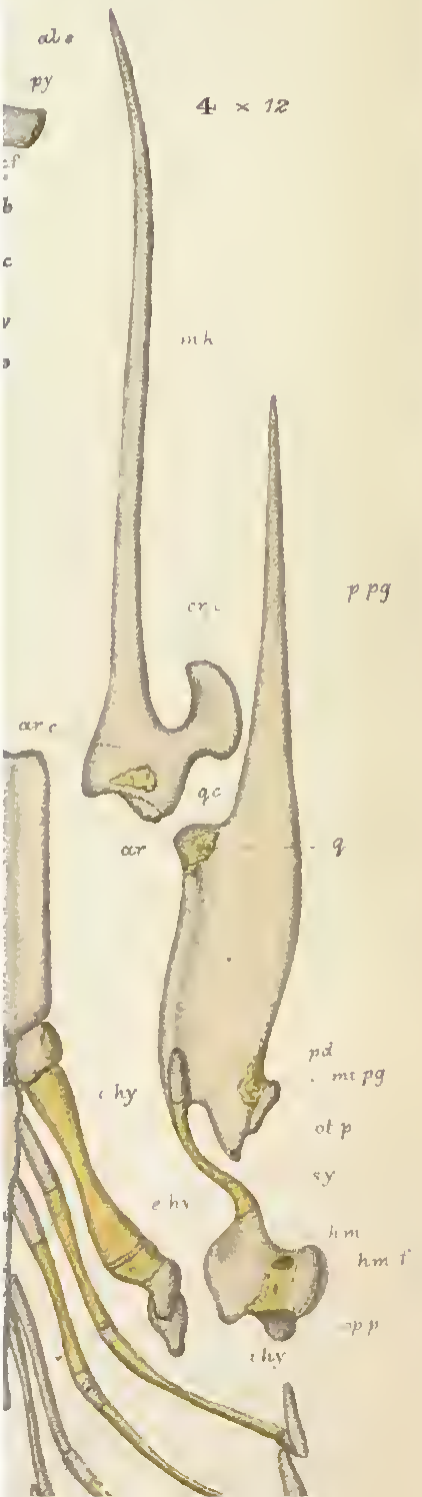
vb
nc
iv
eo
bo
ar c
h hy
h br 1–4

× 15.

th



a br 1–4
b br 1–4.
c br 5

1 × 20
2 × 20
3 × 20
4 × 20
5 × 20
6 × 20
8 × 20
9 × 20
10 × 20
11 × 20
i tr
et n
mx''
pa'
spl
mk
d
I
p pg
mx'
pa s
b hy
m g
c tr
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pg
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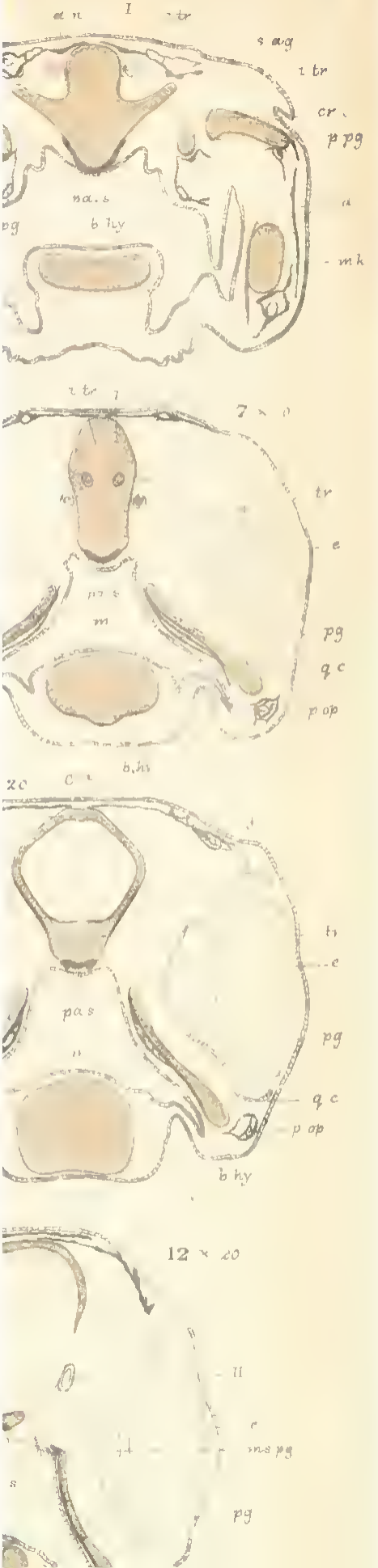
II
ms pg


s ag
i tr
cr
p pg
pg
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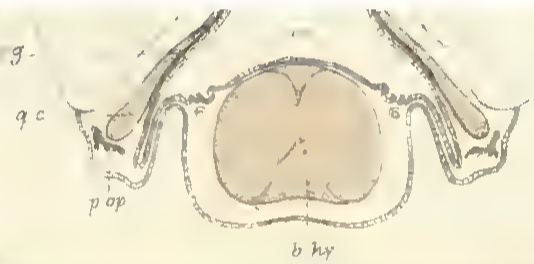
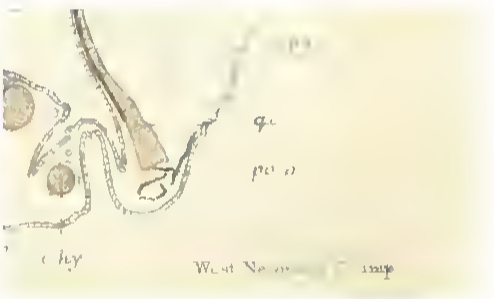
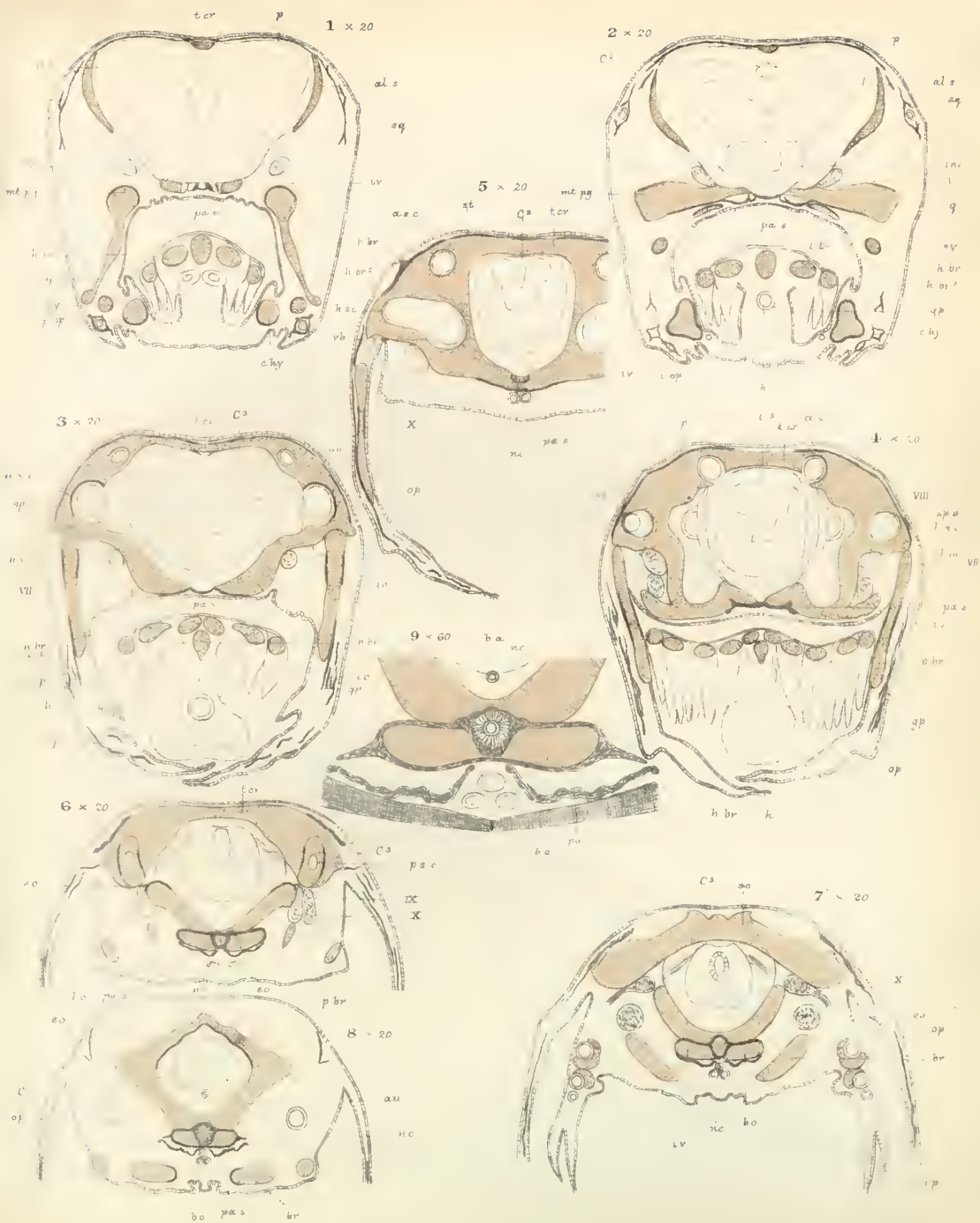


M.P.Parker lith

LEPIDOSTEUS





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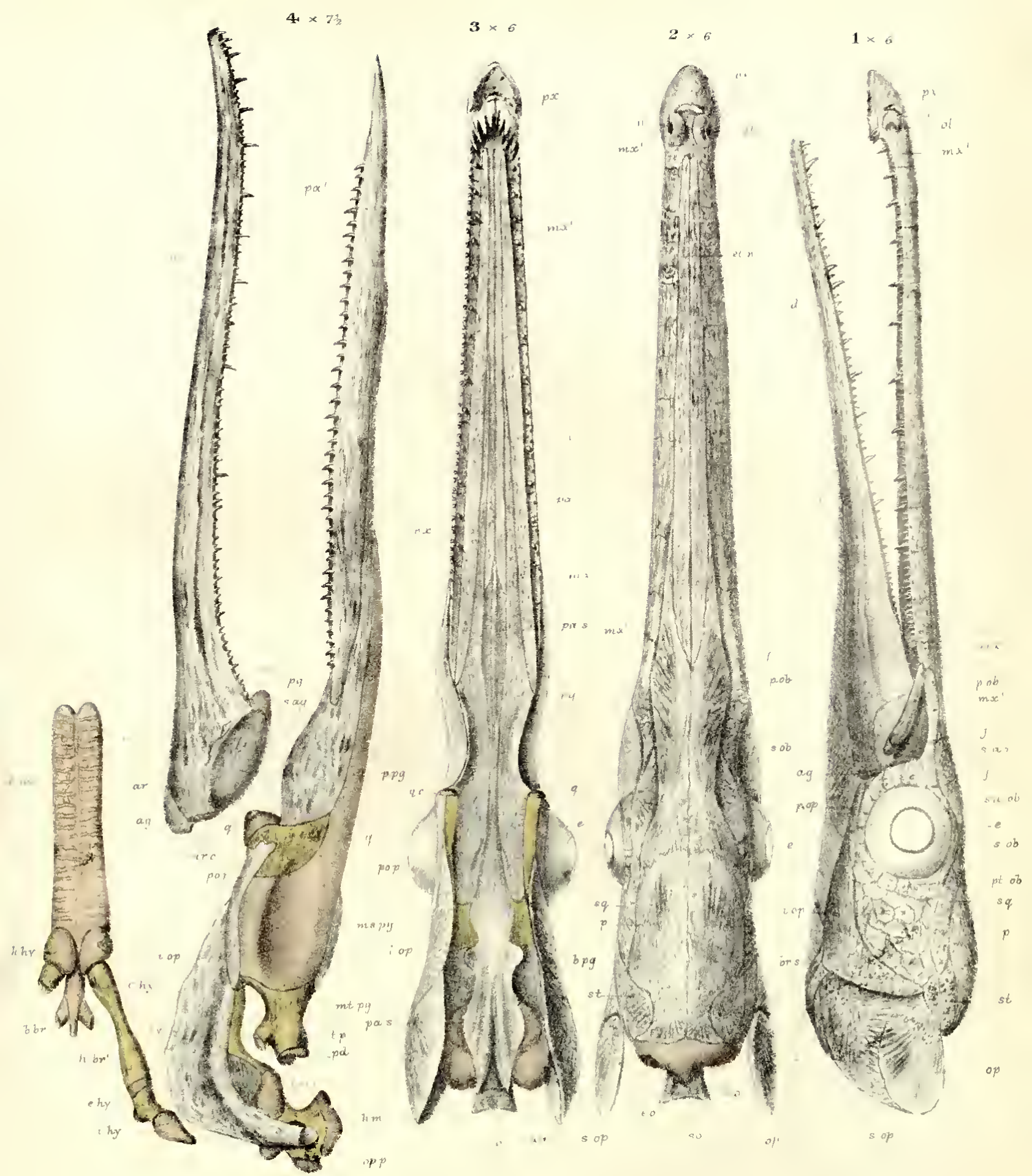

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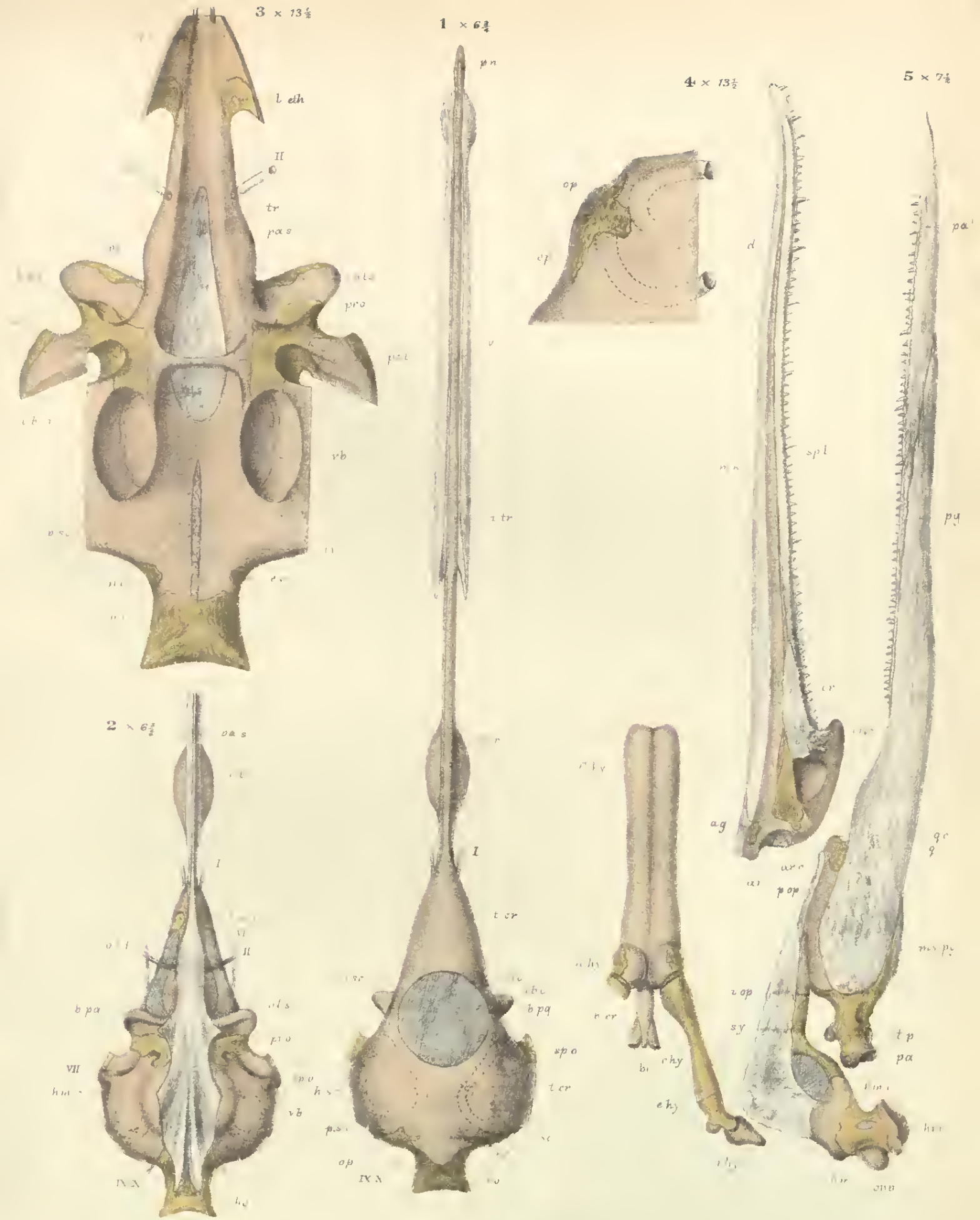

LEPIDOSTEUS